U. S. DEPARTMENT OF COMMERCE
HARRY L. HOPKINS, Secretary
BUREAU OF FISHERIES
CHARLES E. JACKSON, Acting Commissioner

Administrative Report No. 35

PROGRESS IN BIOLOGICAL INQUIRIES 1938

By ELMER HIGGINS

APPENDIX I TO REPORT OF COMMISSIONER OF FISHERIES
FOR THE FISCAL YEAR 1939

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1939

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ADMINISTRATIVE REPORT SERIES

Since the advent of the Administrative Report Series, considerable confusion has arisen concerning its system of numbering the separates composing it. Inasmuch as the Reports of the Divisions vary in order from year to year, many have found their designations as "Appendix No. I, II, III, or IV" very confusing. To relieve this, it has been decided to number them as "Administrative Report No. —." Inasmuch as 20 separates had already been printed in this series before starting the numbers, it was deemed advisable to begin the numbering with Administrative Report No. 21. Of course, numbers cannot be printed on those already off the press, but for the information of those who wish to know what the first 20 were, they are numbered for filing purposes as follows:

No. 1. Report, Commissioner of Fisheries, 1931.
No. 2. Alaska Fishery and Fur-Seal Industries, 1930.
No. 3. Fishery Industries of the United States, 1930.
No. 4. Progress in Biological Inquiries, 1930.
No. 5. Propagation and Distribution of Food Fishes, 1931.
No. 6. Report, Commissioner of Fisheries, 1932.
No. 7. Alaska Fishery and Fur-Seal Industries, 1931.
No. 8. Fishery Industries of the United States, 1931.
No. 9. Progress in Biological Inquiries, 1931.
No. 10. Propagation and Distribution of Food Fishes, 1932.
No. 11. Alaska Fishery and Fur-Seal Industries, 1932.
No. 12. Progress in Biological Inquiries, 1932.
No. 13. Fishery Industries of the United States, 1932.
No. 14. Propagation and Distribution of Food Fishes, 1933.
No. 15. Fishery Industries of the United States, 1933.
No. 16. Alaska Fishery and Fur-Seal Industries, 1933.
No. 17. Progress in Biological Inquiries, 1933.
No. 18. Propagation and Distribution of Food Fishes, 1934.
No. 19. Alaska Fishery and Fur-Seal Industries, 1934.
No. 20. Fishery Industries of the United States, 1934.

Note that the last Commissioner's Report was for 1932. Since then its place has been taken by a reprint from the Report of the Secretary of Commerce under the title "Bureau of Fisheries." Inasmuch as it is no longer a Bureau publication, it is not numbered; but it will be supplied to any who request the Report of the Commissioner for any year since 1932.

PROGRESS IN BIOLOGICAL INQUIRIES, 1938[1]

By Elmer Higgins, *Chief, Division of Scientific Inquiry*

[With the collaboration of investigators]

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[1] Administrative Report No. 35, Appendix I to Report of the U. S. Commissioner of Fisheries for 1939. Approved for publication June 1, 1939.

INTRODUCTION

The fundamental objectives and general characteristics of the research activities of the Division of Scientific Inquiry have been presented at considerable length in the previous annual reports of "Progress in Biological Inquiries" together with detailed reports of the individual research projects. The underlying philosophy of fishery conservation based on a continually growing body of scientific knowledge is now so well understood and the program of investigation under way during the past decade has justified itself so completely, both in its theoretical aspects and its practical applications, that it has acquired a momentum that in itself is a protection against irresponsible diversion of interest or activity into byways of local application or temporary value. A lengthy introduction to the major purposes of the various investigations reported in detail herein is therefore unnecessary.

Each of the recent years has seen the development of new projects of investigation that contribute to a well-rounded scientific program designed to afford still more complete answers to the original questions as to "what diminution in the fish supply of our coastal and inland waters has occurred, to what causes the same may be due, and what remedial measures may be adopted?" With the passing of the years new techniques of investigation have been developed or have been adapted from other fields of scientific endeavor. New concepts of the reactions of marine fish populations to commercial fishing have developed and new knowledge of the natural requirements of fish in inland waters and of means of their management for sustained yield has accumulated.

Time has also permitted the ripening and the fruition of a series of fishery investigations, always time-consuming, so that during the year a number of definitive reports have been completed which, it is hoped, will be published in the near future. At the same time, and coincident with economic recovery, additional appropriations during the past few years have permitted the undertaking of new projects, bringing to hitherto neglected fisheries the benefit of research and the examination of their abuses or deficiencies and paving the way for their ultimate rehabilitation and protection.

During 1938 a new project of considerable magnitude was undertaken by the Division—an investigation of the red-salmon fisheries of Bristol Bay, Alaska. One of the richest and most productive red-salmon fishing areas in the world, Bristol Bay, an arm of Bering Sea in western Alaska, receives endless replenishment from the spawning grounds of five major tributary river systems. The fishery there has developed over many years until it reached a reasonably stable maximum at the beginning of the past decade. Three years ago, however, the fishery was menaced by an exploration seeking to establish commercial fisheries on the high seas to intercept the run

of spawning fish en route to their native streams. The development of a commercial fishery in the offshore waters of Bristol Bay could only result in the disruption of the industry ashore, which takes its supply from coastal waters under strict regulation of the Federal Government, for adequate escapement of fish to the spawning grounds must be assured if the resource is to be maintained. The threat of developing an offshore fishery, therefore, was the occasion, if not the primary cause, of the undertaking of a comprehensive investigation of the Bristol Bay salmon, for the fundamental objective in such a study is to acquire sufficient knowledge of the natural history and the requirements of these fish and the factors that favor or hinder survival of each year's brood to permit a more certain and a more flexible control of the commercial fishery in the interest of wise management.

The investigation has been divided into two major phases—a study of the life of the salmon in fresh water, including the varying success of annual propagation and the factors that affect it and the natural requirements, habits, migrations, feeding conditions, and survival of the salmon during their life in the sea.

With the aid of the United States Coast Guard cutter *Redwing*, a program of hydrographic investigations in the offshore waters of Bristol Bay was undertaken to study the oceanic conditions that so profoundly affect the well-being of the salmon schools. During 1939 this program will be expanded to include experimental fishing to study the schooling of fish, their routes and times of migration, their relative mortality, and the probable effects of the commercial fishery upon the supply. Likewise, a more intensive study of the stream life of the salmon will be undertaken to determine the success or failure of spawning and the responsible factors, in the hope of perfecting a system of prediction of future yields that will simplify the economic exploitation of the fishery and facilitate governmental regulation.

A special fund of $20,000, provided by the appropriation act for the fiscal year ending June 30, 1939, permitted the establishment of another new project of considerable importance. This fund is for the construction, operation, and maintenance of fish screens and ladders on Federal irrigation projects and the conduct of necessary investigations and surveys, preparation of designs, and supervision of construction. It also, for the first time, permits the Bureau to discharge its obligation to determine the requirements for fishways or other fish-protective devices which, under the terms of the Federal Water Power Act of 1924, the Secretary of Commerce is authorized to prescribe at dams constructed under licenses issued by the Federal Power Commission.

With this authority a Hydraulics Section was established, under the supervision of the Division of Scientific Inquiry, employing a competent biologist for the study of fishway requirements and an experienced engineer for the design of the fish-protection facilities. During the latter part of the year the engineer who was first employed not only assisted in the design of fish screens constructed with emergency funds in the Pacific Northwest States, but also redesigned a screen in the Pishkun Reservoir, Montana, which had proved inef-

fective. Important consulting services on screens and ladders were also afforded to other agencies.

This illustrates a recent trend toward the development of service activities as a part of the regular work of this Division. In recent years there has been a rapidly growing number of requests from the State fish and game commissions, fish and game clubs, and other organizations for technical services and advice in connection with stream surveys, stream improvement, pollution surveys, examination of the quality of water in hatcheries or rearing ponds, development of fishing lakes and reservoirs and the screening of their outlets, discovery of the causes of mortality of fish in lakes, ponds, and streams, the treatment of fish diseases in hatcheries, and the like in amazing variety.

It is clearly recognized that satisfying these demands is a valuable function which the Bureau of Fisheries should render to the taxpayers—services that, because of their technical character, can only be furnished by scientifically trained personnel. There is a serious question, however, to what extent the funds appropriated for investigation in a field which so urgently needs the development of fundamental scientific principles should be applied to routine activities which, while locally useful, contribute little to fishery science. Obviously a balance between original research and these practical services should be maintained, for the requests for service are so numerous that if an attempt is made to satisfy them all the major program of scientific investigatiton would be handicapped.

It is not suggested that the Hydraulics Section will not make important contributions to the conservation of the fish supply, particularly in the Northwest where extensive irrigation projects constitute a major hazard to migrating salmon and trout, nor that the studies in connection with the design of fishways or screens will not contribute also to an understanding of the habits and requirements of these fish. The Hydraulics Section, however, is primarily a service agency and hence is properly financed by a separate appropriation.

Normal development and improvements, including minor modifications or extensions of activities, have occurred in all of the other major research projects of the Division, the details of which will appear in the following reports of progress.

COOPERATION

In previous reports the Bureau has been pleased to acknowledge a growing spirit of cooperation in fishery research among the various governmental departments, the States, and private organizations. This trend has been continued during the past year without abatement. Outstanding examples of cooperation in fishery conservation are afforded by the United States Forest Service, United States Bureau of Reclamation, the Coast Guard, and the Tennessee Valley Authority. Many States have likewise contributed either by actually furnishing funds, personnel, or other facilities, or through a less tangible but an equally real spirit of sympathy and support.

The most ambitious cooperative project undertaken by the Division of Scientific Inquiry during the year was a survey of the marine

fisheries of Long Island, N. Y., the major portion of which program was financed by the State Conservation Department and carried out largely by State personnel. Several of the New England States are making active plans to assist in the collection of vitally necessary fishery statistics applicable to the biological problems of maintenance of supply. Specific acknowledgement of cooperation and assistance of many other States and organizations is made in connection with the individual reports of projects.

NORTH AMERICAN COUNCIL ON FISHERY INVESTIGATIONS

Since 1921 the United States has participated, through membership in the North American Council on Fishery Investigations, with Canada, Newfoundland, and France in planning and coordinating studies of the fisheries of the North Atlantic area in which all four nations have a material interest. The twenty-fifth meeting of the Council was held in Boston, Mass., on Oct. 4–7, 1938, at the same time and place that the commercial fishery industries were holding their fishery exposition and convention. The Council invited the members of the Fishery Advisory Committee of the Department of Commerce, and other leaders of the industry, to attend a general session on Oct. 5 at which time fishery problems in the North Atlantic area were discussed and the program of fishery investigations carried on by Newfoundland, Canada, and the United States was presented.

The meetings of the Council are particularly useful in that they afford an opportunity for the investigators of the several fishery departments to discuss their technical problems and to exchange experiences and opinions regarding methods, objectives, and results. Nearly a score of fishery investigators in the various services were present and participated in sectional committee meetings dealing with groundfish investigations, shorefish studies, hydrographic research, and fishery statistics, affording the members of the Council a summary review of progress during the year in these fields and permitting them to modify their official programs accordingly.

COUNCIL OF STATE GOVERNMENTS

During the year important progress has been made toward the solution of vital problems of fish protection on the Great Lakes, where, under the present system of divided control, it is impossible to halt the depletion of the fisheries; and on the Atlantic seaboard, where the migratory nature of many of the important commercial species introduces difficult problems in fishery management and administration. This progress has resulted from the efforts of the Council of State Governments in cooperation with the Bureau of Fisheries and with fishery administrators of the various States concerned.

Two conferences on the problems of the Great Lakes fisheries were held during the year. The first of these, which met in Detroit on Feb. 25–26, was called by the Council of State Governments at the request of the Michigan Cooperation Commission. Action was taken by the Detroit conference as follows: (1) The Federal Government

was urged to discuss with Canadian authorities the establishment of an International Board of Inquiry to consider and recommend measures for the conservation of the Great Lakes fisheries. (2) A special Interstate Committee on Great Lakes Fisheries, consisting of representatives of the Lake States, with advisory members from the Bureau of Fisheries, the State Department, the Province of Ontario, and the Dominion of Canada, was appointed with instructions to offer its services to the State Department as an advisory body and to assist the States in their individual and cooperative efforts to conserve the fisheries. (3) A resolution was adopted urging the legislatures of the various States bordering on the Great Lakes to give their conservation departments discretionary power to promulgate rules and regulations regarding the taking of food fishes.

The Interstate Committee created at the Detroit conference met in Chicago on Dec. 5. This committee reaffirmed its endorsement of an international treaty, and also declared itself in favor of an interstate compact for the control of United States fisheries in the Great Lakes, pending the adoption of an international agreement. The committee again urged the granting of discretionary power to State fish and game commissioners as an aid to securing uniform regulations. Commissioners of Wisconsin, Indiana, and Minnesota now have such powers. It is expected that the legislatures of Illinois and Michigan may pass similar legislation in the near future.

Legislation authorizing the formation of an interstate compact among the Great Lakes States for the preservation of their fisheries has now been passed by the Congress of the United States.

Plans for the conservation of migratory fishes of the Atlantic coast received marked impetus from action taken by the majority of the States from Maine to Florida at the Eastern States Conservation Conference held in New York on Nov. 19. A resolution was unanimously adopted petitioning the Congress of the United States to grant permission to the States to enter into a compact for the protection of migratory fishes in territorial waters. A committee was appointed to prepare a draft for submission to the States. This conference was called by the New York Joint Legislative Committee on Interstate Cooperation and all of the Atlantic Coast States, with the exception of New Hampshire, North Carolina, South Carolina, and Florida, sent one or more delegates. Another conference will be called at some future time to consider a specific draft of the interstate compact before efforts are made to secure its adoption and ratification.

PUBLICATIONS

As was intimated above, a number of important investigations, some of which have been under way for a period of 10 years, have come to completion during the year and reports are now ready for publication. There is considerable doubt, however, at the present time, regarding their probable date of release to the public, for funds available for printing have suffered a progressive decline since 1930. This shortage of funds applies to the publication of the results of investigations by the Bureau as a whole and necessarily restricts and limits the usefulness of the data acquired through many years of

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work and at the expenditure of a considerable sum of money. In 1930 printing funds amounted to 14.2 percent of the amount expended on the various research projects by the Bureau of Fisheries but this percentage has declined until in 1938 only 4.7 percent of the amount of money available for investigation was available for the publication of the results of investigations. It is obvious that the accumulated findings of research, filed without publication, have little value.

Reflecting the meager amount of funds for publication, the following brief list of papers issued during the year is presented.

DAVIDSON, FREDERICK A., and LEROY S. CHRISTEY.
The migrations of pink salmon (*Oncorhynchus gorbuscha*) in the Clarence and Sumner Straits regions of southeastern Alaska. Bulletin No. 25, 24 pp., 5 figs.

DAVIDSON, FREDERICK A., and SAMUEL J. HUTCHINSON.
The geographic distribution and environmental limitations of the Pacific salmon (genus *Oncorhynchus*). Bulletin No. 26, 26 pp., 9 figs.

DAVIS, H. S.
Instructions for conducting stream and lake surveys. Fishery Circular No. 26, 55 pp., 11 figs.

GALTSOFF, PAUL S., W. A. CHIPMAN, A. D. HASLER, and J. B. ENGLE.
Preliminary report on the cause of the decline of the oyster industry of the York River, Va., and the effects of pulp mill pollution on oysters. Investigational Report No. 37, 42 pp.

HIGGINS, ELMER.
Progress in Biological Inquiries, 1937. Administrative Report No. 30, 70 pp.

PEARSON, JOHN C.
The life history of the striped bass or rockfish, *Roccus saxatilis* (Walbaum). Bulletin No. 28, 26 pp., 26 figs.

ROUNSEFELL, GEORGE A., and GEORGE B. KELEZ.
The salmon and salmon fisheries of Swiftsure Bank, Puget Sound, and the Fraser River. Bulletin No. 27, 129 pp., 29 figs.

WALFORD, LIONEL A.
Effect of currents on distribution and survival of the eggs and larvae of the haddock (*Melanogrammus aeglefinus*) on Georges Bank. Bulletin No. 29, 71 pp., 50 figs.

The following papers were published by members of the staff of the Division of Scientific Inquiry during the year 1938, outside of the Bureau of Fisheries series:

DAVIS, H. S.
Fish cultural developments during recent years. Transactions of the American Fisheries Society, vol. 68, pp. 234–239.
Objectives in trout stream management. Transactions of the American Fisheries Society, vol. 68, pp. 76–81.

FISH, FREDERICK F.
Simplified methods for the prolonged treatment of fish diseases. Transactions of the American Fisheries Society, vol. 68, pp. 178–187.
Notes on *Myxobolus inornatus* n. sp., a myxosporidian parasite in the black bass (*Huro floridana* LeSueur). Transactions of the American Fisheries Society, vol. 68, pp. 173–177.

GALTSOFF, PAUL S.
Physiology of reproduction of *Ostrea virginica*. I. Spawning reactions of the female and male. Biological Bulletin, vol. LXXIV, No. 3, pp. 461–486.
Physiology of reproduction of *Ostrea virginica*. II. Stimulation of spawning in the female oyster. Biological Bulletin, vol. LXXV, No. 2, pp. 286–307.
Source of calcium for shell in *Ostrea virginica*. Nature, vol. 141, p. 922.
The U. S. Bureau of Fisheries Laboratory at Woods Hole. The Collecting Net, vol. XIII, No. 2, pp. 29–32.

GINSBURG, ISAAC.
Arithmetical definition of the species, subspecies and race concept with a proposal for a modified nomenclature. Zoologica, vol. 23, pp. 253–286.
Eight new species of gobioid fishes from the American Pacific Coast. University of Southern California Publ., Allan Hancock Pacific Exp. vol. 2, pp. 109–121.
Two new gobiid fishes of the genus Gobiosoma from Lower California. Stanford Ichthyological Bulletin, vol. 1, pp. 57–59.

HERRINGTON, WM. C.
Problems of New England Fisheries. Atlantic Fisherman, vol. XIX, No. 11, pp. 9–10.

HIGGINS, ELMER.
Fish outlive officials. State Government, vol. 11, No. 3, pp. 53–54–58.
Shall our marine fish resources be squandered, hoarded, or managed—and how? Transactions of the Third North American Wildlife Conference, pp. 151–158.

HILDEBRAND, SAMUEL F.
A new catalogue of the fresh-water fishes of Panama. Field Museum of Natural History, Zoological Series, vol. XXII, No. 4, pp. 219-359, 13 figs.
Twinning in turtles. The Journal of Heredity, Vol. 29, pp. 243–253, 5 figs.

HILE, RALPH, WILL SCOTT. and H. T. SPIETH.
The bottom fauna of Tippecanoe Lake. Investigations of Indiana Lakes and Streams, No. 4. Indiana Department of Conservation in cooperation with the Indiana University Biological Station, pp. 3–16.

LINDNER, MILTON J.
The cooperative shrimp investigations. Louisiana Conservation Review, Spring 1938, pp. 24–26, 38; and Thirteenth Biennial Report, Louisiana Department of Conservation, pp. 447–455.

LOOSANOFF, VICTOR L.
Extermination of starfish by chemical. Atlantic Fisherman, vol. XIX, No. 4, pp. 8–9.

LOOSANOFF, V. L. and J. B. ENGLE.
Chemical control of starfish. Science, vol. 88, No. 2274, pp. 107–108.

NEEDHAM, PAUL R.
Trout Streams. Pp. VIII–233. 74 figs., 26 tables, Ithaca, Comstock Publishing Company.

NEVILLE, WILLIAM C.
Some results of the Bureau's study of the marine fishes of the Middle Atlantic States. Yearbook for 1938 of the Ocean City Fishing Club, New Jersey.
Some benefits that may be derived from a scientific study of the marine fisheries of Long Island, New York. Yearbook for 1938 of the East End Surf Fishing Club, Riverhead, N. Y.

PRYTHERCH, HERBERT F.
Life-cycle of a sporozoan parasite of the oyster. Science, vol. 88, No. 2289, pp. 451–452.

SMITH, OSGOOD R.
Fact finding surveys in the Sacramento drainage basin. Associated Sportsmen, vol. 5, pp. 5 and 12.

SURBER, EUGENE W.
A comparison of four eastern smallmouth bass streams. Transactions of American Fisheries Society, vol. 68, pp. 322–333.

VAN OOSTEN, JOHN.
The age and growth of the Lake Erie sheepshead, *Aplodinotus grunniens* Rafinesque. Papers, Michigan Academy of Science, Arts and Letters, vol. XXIII, pp. 651–668.
From cisco to perch to pike. State Government, vol. 11, No. 3, pp. 55–57.
Michigan's commercial fisheries of the Great Lakes. Michigan History Magazine, vol. 22. No. 1, pp. 3–39.

VAN OOSTEN, JOHN and HILARY J. DEASON.
The food of the lake trout (*Cristivomer namaycush namaycush*) and of the lawyer (*Lota maculosa*) of Lake Michigan. Transactions, American Fisheries Society, vol. 67, pp. 155–177.

MULTIGRAPHED PUBLICATIONS

United States Bureau of Fisheries.
The Progressive Fish Culturist. Memorandum I–131, 8 issues.

Progress reports of the investigations conducted by the various sections, prepared in the main by the section heads, are given in the following pages:

NORTH ATLANTIC FISHERY INVESTIGATIONS

William C. Herrington, *in charge*

On the basis of landings at the three principal New England ports during the first 11 months of the year, the total catch of the New England vessel fisheries during 1938 will be approximately 4 percent greater than that during the previous year, but the value will be 9 percent less. The increase in catch is largely the result of considerable increases in the landings of redfish (rosefish), whiting, and mackerel, which more than offset declines in haddock and cod. The decrease in value reflects the decline in price for nearly all species.

The past year also witnessed a general slowing down in the program of replacement of the old steam trawler fleet by modern vessels. During the year, but 3 new trawlers of the so-called super-trawler class were launched, compared with 10 during the previous year. The addition of new boats to the fleet has been partially or completely balanced by the decommissioning of older boats, so that the total intensity of the fishery did not change as much as the construction of new boats would indicate.

Probably the outstanding development in the New England fisheries during 1938 was the recovery of the mackerel fishery to more normal proportions after the disastrous year of 1937, and the start toward the development of a commercial tuna fishery in the Gulf of Maine. From the total of 14,000,000 pounds landed in 1937, the mackerel catch increased to 29,000,000 pounds in 1938; while the offshore tuna fishery showed an increase from around 110,000 pounds in 1937 to about 760,000 pounds in 1938.

The catch of both cod and haddock declined somewhat from that of the previous year, but it has not yet been possible to make a sufficiently complete study of the factors involved to determine whether this decline was due to a decreased fishing effort or to a decreased abundance of fish. Probably the most significant trend in the haddock fishery was toward the greater concentration of the fishery on scrod haddock, a trend which it is believed is definitely prejudicial to the future of the fishery.

Development of a Gulf of Maine shrimp fishery appears to be definitely under way. In the spring of 1938, between February and April, a total of about 75,000 pounds of shrimp was landed at Portland by small otter trawlers which caught them in inshore waters along the coast of Maine and New Hampshire. Smaller quantities were landed at other ports.

In the New England offshore fishery, the principal problems continue to be the determination of the causes of the great fluctuations in yield and the development of methods which, if adopted by the industry, will reduce these fluctuations and maintain the yield at the

highest practical level. Although good progress is being made on the species now under study (haddock, flounders, and mackerel), no biological work has been possible on the highly important fisheries for cod, redfish, pollock, and swordfish.

Pressing problems are developing in the inshore fisheries which support the small-boat fishing fleet and coastal population on long stretches of the North Atlantic coast. The most important problems here involve the improvement or maintenance of fisheries for flounders and lobsters, and the development of the fishery for shrimps.

Several important changes in the personnel of the North Atlantic staff were made during the year. J. R. Webster was assigned to continue the mackerel investigations, following the transfer of O. E. Sette to the West coast in October 1937, to assume charge of the Bureau's South Pacific Investigations. In January 1938, M. J. Lobell was transferred to this staff to carry on an investigation of the important flounder fishery; and in March 1938, Dr. G. A. Rounsefell also was transferred to carry on a comprehensive study of fluctuations in the abundance of North Atlantic groundfish, a problem which has demanded attention for some time.

The headquarters of the North Atlantic Fishery Investigations has remained in Cambridge and Boston, Mass. Harvard University has generously provided the staff with space and facilities in its biological laboratories. The cooperation of the Woods Hole Oceanographic Institution is gratefully acknowledged, as is the personal advice and interest of Prof. Henry B. Bigelow. The assistance and cooperation of fishermen and dealers in providing the use of their records, and in other ways, is also acknowledged with pleasure.

HADDOCK

The past year witnessed the continuation of several trends discussed in previous reports, but no noteworthy innovations or developments. Catch records for the first 11 months of 1938 (the only months yet available), show that the total amount of haddock landed at Boston, Gloucester, and Portland reached 138,000,000 pounds, a decrease of about 3 percent from the previous year; while the value was a little over $3,000,000, a decrease of 15 percent from the previous year. This is the third successive year of decline in catch and the second successive year of decline in value since 1935.

The replacement of the old steam trawler fleet with new Diesel-powered boats continued during 1938, but at a slower pace than in 1936 and 1937. Two new trawlers launched late in 1937 began fishing in 1938, and three others were launched and placed in operation during the late fall and winter. However, these additions to the fleet do not necessarily mean a greater fishing intensity since they were probably more than counterbalanced by the decommissioning of old steam trawlers. The total number of trawler days at sea was somewhat less than in 1937, but the increased effectiveness of the new units probably compensated for much of the decline and it is likely that more detailed analysis will show that there was little change in absolute fishing intensity between 1937 and 1938.

The trend toward the increased utilization of species other than haddock continued, but at a much lowered tempo. These species, which in 1929 made up 34 percent of the landings of groundfish, in

1938 constituted about 64 percent. This change in the make-up of the catch is due primarily to the great increase in recent years in the landings of redfish (rosefish), whiting, cod, pollock, and grey sole. To a lesser extent it is due to the decline in the catch of haddock.

Another trend which was continued in 1938 was the increased concentration of fishing on scrod haddock, when these sizes were available. During the first 11 months of 1938, 45 percent of the haddock from Georges Bank were scrod, compared to 35, 38, and 36 percent during the 3 previous years and even lower percentages prior to that time. This appears to be definitely prejudicial to the future, inasmuch as haddock of this size still are growing rapidly and would be of considerably more value to the fishermen because of increased weight and increased value per pound, if allowed at least 1 more year's growth.

As a result of rather erratic exploitation and of natural factors which were neither understood nor even known, the catches of haddock have varied tremendously in different years, indicating a high degree of fluctuation in abundance or availability. Following 1927 the average catch per boat declined to an alarming extent (although the total catch was maintained until 1929–30 as the result of a great increase in fishing effort), and since then, has remained at a relatively low level. The fishery on the Nova Scotian banks has followed about the same course and the effects have been much the same.

The principal problems of the haddock investigation, from its inception, have been to determine the extent and causes of these great fluctuations, and to determine what practical modifications in fishing methods or procedure could be adopted in order to partially or entirely eliminate the periods of low productivity. The final problem was to develop a plan for prosecuting the fishery which, if adopted by the industry, would permit the maximum continuous catch from the area.

Analysis of extensive data collected during the course of the investigation has explained many of the factors controlling the condition of the fishery. During the period under most intensive study, the total catch increased from about 60,000,000 pounds in 1921 to nearly 250,000,000 in 1929, then dropped to about 140,000,000 in 1932 with some relatively limited increases and decreases since then. On the average, about 72 percent of this catch came from the Georges Bank area. In this region, the abundance of haddock, as shown by the average daily catch per trawler, had decreased rapidly from a relatively high level in 1921 to a low point in 1923, and had then risen precipitously to a peak in 1927. Since that year there has been a decline to an extremely low level in 1931, with little recovery since. The changes in this apparent level of abundance, particularly the low levels maintained since 1932, were due partly to the changing intensity of the fishery; but the relative success or failure of year-class survival appears to have been a very important factor. Years of good and poor survival appear to occur in cycles, the causes of which are only beginning to be understood.

Independence of the haddock population in the Georges area from that on the Nova Scotian banks has been apparent. During the first two or three years of life, the growth rate for Georges fish is much greater than for haddock from the banks to the east; while in later

years, the advantage is reversed. In most of the years for which data are available, the size composition of the populations in the two areas was entirely different.

The principal spawning ground in the Georges area is on the eastern part of Georges, although, in some years, there has been a considerable concentration of spawners in South Channel. The principal nursery ground for one-year haddock is on southeastern Georges, while the other fish move further to the north and west as they grow older. These sizes also carry on much more extensive seasonal migrations (within the limits of this area) than the yearlings and 2-year olds.

Progress in 1938.—The investigation has continued under the direction of W. C. Herrington assisted by H. M. Bearse and M. S. Moses with assistance from J. R. Webster and G. A. Rounsefell on the *Atlantis* trawling trip, and from the latter on a tagging trip to the Maine coast.

Dependable figures for total catch and relative abundance, by years and areas, have been and continue to be of primary importance to this investigation. For the past several years, it has been evident that recent data on relative abundance obtained from analysis of the haddock catch alone might not be entirely comparable to earlier years, because of the increasing importance of other species in the catch of the otter-trawl fleet. Although about 1929 haddock made up 60 to 70 percent of the catch of this fleet, in 1936 it comprised only about 36 percent. To determine the extent to which this increase in the catch of other species would affect the unit of fishing effort as applied to haddock alone, a comprehensive analysis of the entire catch taken by the fleet was necessary. During 1938, such analysis of groundfish catches was undertaken by Dr. Rounsefell. Since this work did not get under way until well on in 1938, no data are yet available as to the relative level of haddock abundance in 1938, or changes that occurred from 1937 to 1938.

Field work during 1938 consisted principally of the regular observations on the Boston Fish Pier and a trawling trip on the *Atlantis* in April–May. Data collected on the Fish Pier by H. M. Bearse included more than 55,000 length measurements, 3,000 scale samples, and interviews showing fishing grounds, fishing effort, and division of catch for all groundfish trips. The *Atlantis* trawling trip was under the direction of J. R. Webster assisted by G. A. Rounsefell and H. M. Bearse. Records were obtained covering "catch-per-hour's-trawling" for haddock and other species, and data were obtained concerning length, sex, and age for all haddock as well as for part of the cod and other species.

Analysis of abundance.—Original records for the otter-trawl fishery from 1914–22 have now been acquired. These new data are of inestimable value, as they include information on the scrod catch not previously available. Primary analysis of the data for the entire period 1914–37 has been virtually finished. When completed, this will show the average catch per trawler per day of large haddock, scrod haddock, and total fish, for a series of years extending from the time when the commercial fishery was relatively small to the present extremely intensive fishery. Preliminary conclusions from these data indicate that cycles of relative scarcity and abundance have appeared

in the haddock populations over the entire period, which is marked by three periods of scarcity and two of abundance. Periods of abundance apparently result from a series of years with a high survival of young, while periods of scarcity result from a series with a poor survival. The years since 1930 are an exception, for since then the level of abundance has remained relatively low in spite of the consistently good production and survival of young. This condition appears to be the result of the increased intensity of the fishery in recent years. Cycles of good and poor survival of young appear to be related to the abundance of adults on the nursery grounds, the most favorable level being approximately that which prevailed in 1922 to 1924, 1929, and 1936.

These developments indicate that we are now approaching the stage where it will be possible to explain the causes for the great cycles of abundance which have been observed in the haddock fishery. It appears that the cycles of abundant and poor year classes are related to the varying abundance of large fish on the banks. Poor production or survival of young may result either from an overabundance of adults on the nursery grounds or from too great a reduction in the spawning stock. If the completed analysis of the material substantiates these indications, it will provide information of tremendous value toward development of a consistently good yield.

Population composition.—A considerable amount of information concerning the abundance and distribution of haddock was obtained from the trawled material taken on the spring *Atlantis* trip. One- and two-year fish were abundant, but older fish were relatively scarce. The 1-year fish were distributed about as in previous years, but 2-year fish, which previously were found in great numbers on Central Georges, in 1938 were almost entirely absent from this region. They were found in large numbers only on southeastern Georges and in South Channel. The latter location was particularly unusual, as but few fish of this age had been found there in previous years.

Tagging.—Early in this investigation a series of tagging experiments was carried out, using haddock held in tanks and live cars to determine the most satisfactory tag for this species. A variety of special tags were tested in addition to the disk type (plaice label) and strap tag used by other investigations. The experiments indicated that a button type was most successful with the disk type almost as good. This work was followed by field experiments in 1932-33, involving the tagging from otter trawlers of 440 haddock with button tags and 52 with belly tags, and from line trawlers of 296 with button and 117 with belly tags. No returns were received from any of these experiments except for one button tag from the line-trawl tagging. In view of the successful retention of tags in the live-car experiments, it appeared that the failure of the offshore work was the result of high mortality due to the gear and depth. Experiments next were tried from small line trawlers in shoal water along the Maine coast. In this attempt, 296 button and 117 belly tags were attached. There were 6.4 percent of the button and 6 percent of the belly tagged fish recaptured and reported.

Owing to limited personnel and funds, no further work could be done on this subject in spite of its importance until Dr. G. A. Rounsefell took charge of the work in 1938. In June of that year, 265 haddock were tagged with button tags, 266 with disk tags, and 100

with an internal anchor tag designed by Dr. Rounsefell. Tagging was done near Mt. Desert Island from a small line trawler. It is planned to continue the work next year on a sufficiently large scale to provide significant conclusions concerning the intermigration between the population of Maine shore haddock and that on the offshore banks.

Principal requirements of the investigation.—The most urgent matters now facing the investigation are the completion of the study of variations in haddock abundance and total catch, analysis of the age and size composition of the commercial catch to show the effect of year-class strength on the fishery, study of the differences in growth rate between different year classes and fishing grounds, and the determination of the extent of intermigration between the various grounds. The first is now well on the way toward completion, but, although considerable progress has been made on the others, the work has been greatly handicapped by the lack of vessel facilities for collecting basic data on the offshore fishing grounds. The generous cooperation of the Woods Hole Oceanographic Institute in providing the occasional use of the *Atlantis* at nominal cost to the Government has been of great help, but to no considerable degree has this served to displace the need for a vessel built and equipped for otter trawling and hydrographic duties and regularly assigned to fisheries work. Such a vessel is particularly needed for a systematic sampling of the young fish population at least twice a year to evaluate the distribution and abundance of each year class before it reaches commercial size; determine its mortality rate from natural causes and from the commercial fishery; and study the growth rate of the young fish.

A vessel is urgently needed to carry on further work on offshore tagging. Adequate experiments should provide data of great value concerning haddock migrations, growth rates, and mortality rates. Preliminary attempts to carry on the work from commercial vessels have proved to be a complete failure (except from small line trawlers along the Maine coast), presumably because of the high mortality of the fish resulting from the effects of the commercial gear. It does not appear that these difficulties can be overcome without the use of a research vessel to develop and use special methods for catching and handling the fish.

MACKEREL

The 1938 mackerel season began late in March, and, because of growing emphasis on winter activity following the 1937 failure, was still in progress at the end of the year. Total vessel landings for the season will be approximately 29,000,000 pounds, about double the 1937 catch. Prices dropped back to the 1936 level, close to 2½ cents a pound, at principal New England ports. In general, fishermen fared better than in 1937.

Throughout its history the mackerel catch has been characterized by extreme fluctuations in yield. The mackerel investigation was undertaken to study the causes of these fluctuations, with a view to devising means of predicting the relative abundance of mackerel in advance of the season.

To provide a basis for understanding changes in abundance, catch statistics have been assembled covering the fishery from its inception—about 1804. These figures reveal a period of high catch level,

lasting from about 1820 to 1885. During this time the landings averaged roughly 80 to 100 million pounds annually, but were subject to violent fluctuations. The year 1886 ushered in a period of poor catches, lasting until the present day. In no year during this period have landings exceeded 65,000,000 pounds, while the annual average has been nearer 40,000,000 pounds. This low level has persisted so long as to be considered normal. However, the yearly fluctuations during the latter period, though less in amount, were as great in degree as those within the former period.

Investigations of mackerel behavior and life history have demonstrated that these fish range from the Middle Atlantic States to Canada. They school mostly over the inner portions of the continental shelf, generally avoiding small enclosed bays and regions over deep water. Analysis revealed two contingents in the population; one ranging between the offing of Chesapeake Bay and the Gulf of Maine and the other between southern New England and the Gulf of St. Lawrence. Both contingents probably spend the winter in offshore areas near the southern portions of their range.

Spawning occurs between April and August. Fish grow 7 to 10 inches the first season, and attain a length of 10 to 14 inches by the end of the second year. Thereafter, growth is slower. The maximum life is 12 to 15 years, length about 22 inches, and weight from 3½ to 4 pounds.

Fish from one or a few year classes usually make up a season's catch, and persist as definite groups for many years. Discovery of this fact led to the belief that the numerical strength of these dominant year classes determines the success of the commercial fishery. On the basis of year class recruitment and mortality the investigation succeeded in forecasting the approximate yield for several successive years. In 1937, however, the mackerel catch fell about 40 percent below the predicted decline, indicating that some unknown factors were at work.

Progress in 1938.—The current mackerel investigations, now under the direction of John R. Webster, have been devoted to completing and bringing up to date the lines of investigation initiated by O. E. Sette, and to determining the factors which caused the relative failure of the mackerel fishery in 1937.

The abundance analysis for 1937 was based on more than 1,500 catch records and 35,000 length measurements. As shown by catch per unit of effort, abundance fell off everywhere along the coast. Compared to 1936, this decline was not much more than 30 percent for the area west of Nantucket Shoals, but exceeded 50 percent in the Gulf of Maine area.

Study of lightship temperature records revealed that the surface waters of the extreme western Gulf of Maine in 1937 ran from 2° F. to 7° F. higher than those of the previous 10-year average. The departure from this norm was greatest during that portion of the mackerel season when the fleet operated in these waters. Since the offshore fishery fell so far below expectations during this period, it is suspected that hydrographic conditions were a factor in the decline.

Composition of the whole mackerel population in 1937 apparently differed from that of previous years since 1925. Analysis of length-

frequencies furnished strong evidence that the 1923 year class was still present, and probably the 1928 class as well. Except for the 1932 class, year classes following 1929 were present in better than 5 percent strength each. None of these stood out as dominant, however, a real departure from conditions only a few years before.

Field work during 1938 was conducted principally by F. E. Firth. This included details at Cape May and New York City in April and May, and at the Boston Fish Pier for the remainder of the year. Information on fishing effort and catch locations was obtained for over 1,000 trips and about 50,000 mackerel were measured for population composition analysis. In addition, 700 scale samples were taken for age reading reference. Late in June, Mr. Webster tagged 500 mackerel at Provincetown. There were but 5 returns, all local, within 1 week.

Preliminary studies of the 1938 catch show that the 1936 year class made large contributions to the fishery, with the combined groups of 1934 and 1933 next in importance. Detailed analysis of these data will be undertaken in 1939.

The present tendency of the seining fleet to extend both ends of the season may make necessary some changes in methods of determining abundance. For furthering studies of hydrographic conditions, it appears advisable also to obtain a more representative norm of coastal surface water temperatures. If temperature be a real factor affecting the availability of mackerel, some measure of its significance must be found. Although some advance in the solution of these problems can be made with our present facilities, expansion is necessary in order to solve others. Direct evidence is needed of the fate of certain year classes which decrease in availability faster than others. The cause may be heavier mortality or mass changes in habitat through migration. A large-scale tagging program is needed to determine this point. Further study is needed also for an understanding of the relationship between the mackerel catch by purse seiners and pound nets in the same locality. Catch statistics alone are insufficient, since it is necessary to learn when these two types of gear sample the same or different populations and why. The aid of part-time assistants at strategic points is needed to collect such information.

The mackerel problem now appears to involve more than a study of year-class recruitment and mortality. Events of the past 2 years have emphasized the need for particular knowledge of oceanic conditions affecting the mackerel fishery. In view of these facts, it is believed inadvisable to attempt forecasts of future abundance until facilities for determining these conditions are provided.

FLOUNDER

In 1935, the last year for which complete figures have been compiled, the total North Atlantic catch of all species of flounders amounted to about 39,000,000 pounds, and was worth approximately $1,500,000. Five species compose the bulk of the catch. They are: (1) Lemon sole (*Pseudopleuronectes dignabilis* Kendall); (2) gray sole or witch (*Glyptocephalus cynoglossus* Linnaeus); (3) winter flounder or blackback (*Pseudopleuronectes americanus* Walbaum);

(4) dab (*Hippoglossoides platessoides* Fabricius); and (5) yellowtail (*Limanda ferruginea* Storer.) In addition, the fluke (*Paralichthys dentatus* Linnaeus), the four-spotted flounder (*Paralichthys oblongus* Mitchill), and the smooth flounder (*Liopsetta putnami* Gill) are landed in some quantities. Because of variations in life history and habitat, each of these species represents a different problem.

Studies of winter flounders previous to 1938 were confined largely to tagging experiments. In 1931, R. A. Nesbit tagged a number of flounders at Woods Hole and devised the present methods of flounder tagging. Returns indicated that the winter spawning population dispersed in various directions during the spring and summer, and that long migrations were undertaken by some individuals. In the following winters many of these tagged flounders were recaptured at the original tagging area. During 1937, a number of fish were tagged in Rhode Island and in Great South Bay, Long Island. The recoveries from these experiments indicated a high intensity of recreational fishing. As before, returns indicated a dispersion from the tagging point. Little migration from Rhode Island waters occurred, a few fish being recovered in the Nantucket region. Significant numbers of fish tagged in Great South Bay were recovered at considerable distances from the tagging area, some individuals being taken as far away as Nantucket Shoals.

In January 1938, Milton J. Lobell began an intensive study of the flounder fisheries of the North Atlantic area. The most pressing problem facing this investigation is to determine whether a decline in abundance is in progress. If the decline is serious, the reasons for it must be found and methods developed for a more efficient utilization of the stock. Determination of the total catch and catch per unit of effort must be made to cover as long a period as possible in order to determine the condition of the stock and the fluctuations in the fishery. To find the reasons for fluctuations in abundance or availability, various biological factors must be studied. These include the racial composition of the stock, age and growth, migrations, and many other problems that affect the abundance and availability of the species.

Statistics.—The first available figures for the North Atlantic flounder fisheries are for the year 1887. During this year a total catch of about 2,500,000 pounds was recorded. The peak year for flounder landings occurred in 1928, when approximately 51,000,000 pounds were reported. The years 1929 and 1930 were also important, since landings of about 49,000,000 pounds were made in each of these years. Although the value of the fishery cannot be accurately determined for the earlier years, in more recent times a basis of estimation is furnished by the value of flounders landed at the three principal New England ports, Boston and Gloucester, Mass., and Portland, Maine. In 1928, a 10,500,000 pound catch landed at these ports was valued at $511,296. Since the total reported catch in 1928 for the whole region was about 51,000,000 pounds, or approximately 5 times as much, it can be conservatively stated that the value of the fishery was well over $2,000,000.

The catch by species was given for the first time in 1937 in the statistical reports of the Bureau for the three principal New England ports. Gray sole landings were almost 8,000,000 pounds;

yellowtail about 4,000,000; lemon sole, 2,500,000; dabs, 2,500,000; and winter flounders slightly over 1,000,000 pounds. These figures, however, are not indicative of the total amounts landed by the entire fishery, or even of the proportions of the catch contributed by each species in New England and New York. Contrary to the situation prevailing north of Cape Cod, the bulk of the flounder catch south of the Cape is composed of winter flounders. Annual canvass figures for this area showed a decided decline, the landings having dropped about 37 percent from 1930 to 1935. Fishermen and dealers report a definite decrease in the average size of the fish. During the past 5 years an enormous sports fishery for winter flounders has developed south and west of Cape Cod, and particularly in Long Island. In some places the catch equals or even exceeds that of the commercial gear. In view of the decline of commercial catches of the winter flounder and the rising importance of the sports fishery, the work of the flounder investigation has been concentrated on this species.

Detailed and accurate statistics of the catch of winter flounders are not available for past years, owing to the fact that all species landed were lumped together, with no record of seasonal occurrence or grounds fished. In 1938, however, the Market News Service, with offices in Gloucester, Portland, Boston, New Bedford, Provincetown, and New York City, was able to furnish more complete and detailed statistics than could be procured formerly. In addition, the State of New York, through its Long Island Survey, collected much needed and detailed information on its fisheries. The State of Maine will adopt a statistical system in the early part of 1939, and other New England coastal States are expected to undertake a like program. With cooperation from these States, it will be possible to obtain more satisfactory data in the future.

Tagging.—In cooperation with the States of New York and Connecticut, about 2,000 flounders were tagged in Long Island Sound and in a number of localities on Long Island. Fish were tagged in Great South Bay, Great Peconic Bay, Gardiners Island Sound, Port Jefferson, and Huntington Harbor in New York waters. In Connecticut, tagging of the local stock was conducted in the Mystic River and of the breeding stock at the Noank Hatchery. As in previous experiments, the twin disk celluloid tag was used. These were fastened just posterior to the head and below the dorsal fin of the fish by means of nickel pins.

These experiments yielded valuable information on the movements of flounders and the relative intensity of the commercial and sport fisheries. The peaks of returns occurred from April to May and from October to November, indicating either that the fish were more available at that time or that fishing was more intensive. In general, an offshore movement in the spring and an inshore movement in the fall occurred. Summering concentrations in the Block Island region were composed of individuals from Long Island, Connecticut, Rhode Island, and the south shore of Cape Cod. Recoveries from Nantucket Shoals suggest that the offshore banks may be partially populated with fish from inshore grounds. Although a general dispersion of fish was indicated, evidences of directional migrations also occur, since it was found that in a number of cases minimum speeds of over 4 miles a day were recorded. The recovery of a large num-

ber of tags by recreational fishermen indicated that this type of gear took almost as many fish as the commercial gear in the tagging areas. Since year-round recoveries were made near the tagging locality, while seasonal recoveries occurred from points relatively far removed, it may be concluded that racial types, or at least groups with differing summer habitats, exist.

Age and growth.—Scale samples from Long Island flounders collected by the Long Island Survey and from Narragansett Bay, supplied by the Narragansett Marine Laboratory, were prepared, read, and the results partially analyzed. Particular attention was paid to the Long Island collection, since these data will be of value in connection with the survey conducted by the State of New York.

It was found that length frequencies, except for the 0-group and to some extent for the I-group, were useless in determining ages of flounders because of the multi-moded character of the length frequencies of fish other than the 0-group. Examination of the scales proved to be more enlightening, although the reading of some scales was complicated by false checks, double checks, and regeneration marks. Comparison of age and length availed but little, since oftentimes fish with two definite checks might be larger than fish with three definite checks, even in the same sample. In addition, it was found that females were consistently larger than males of the same age. Samples from one area showed growth rate differences when compared to samples from other regions. This evidence definitely indicates that the population of flounders is composed of groups with varied growth rates and possibly different habits in other respects. In general, the size at each age is: End of first year, 4⅜ inches; end of second year, 7½ inches; end of third year, 9⅞ inches; end of fourth year, 11½ inches; end of fifth year, 13 inches; and end of sixth year, 13¾ inches.

Races.—In addition to positive evidence of the existence of separate races from tagging recoveries and age and growth studies, examination of the characteristics of juvenile fish also indicates that differences exist. These differences are in the length-width ratio, degree of twist in the snout, angle of head profile, location of the eyes, and ratio of head length to total length. Preliminary findings suggest two types of flounders: A thin, narrow-bodied type with the snout sharply twisted, a low head profile and a large head; and a relatively thick, wide-bodied type with a straight snout, high head profile, and small head. It is thought that these two types represent the offshore and inshore races, since both groups are known to spawn in the same general areas.

These general lines of investigation will be continued in the future, with emphasis on the collection of detailed and reliable catch statistics and on a thorough study of the life history.

ANALYSIS OF GROUNDFISH ABUNDANCE

Analysis of groundfish abundance was undertaken early in 1938, under the direction of Dr. George A. Rounsefell. For some time the need of this work has been increasingly apparent because of serious problems created by this rapidly expanding fishery.

New England landings of fish and shellfish from 1930–35 (excluding 1934 for which figures are not available) have averaged

611,000,000 pounds annually, of which 437,000,000 pounds consisted of the various species of groundfish. Fluctuations in the abundance of haddock, which comprised about 45 percent of the catch during the above period, have been determined as part of a biological study of the species, but no information has been available concerning the other species—cod, pollock, hake, cusk, wolffish, whiting, halibut, rosefish, and the various flounders. During recent years the industry has been developing markets for all species, bringing about a marked change from former years when boats sought only haddock, and took other species but incidentally. This means that the total catch of any one species is now partially dependent on the abundance and market value of the others.

Various other factors must be considered in an analysis of groundfish abundance. For example, in a fishery that draws upon several species, the relative abundance of any one species is not necessarily indicated by the average catch of that species per unit of fishing effort. The average catch must be qualified by such information as the depths and grounds fished and the quantities of other species caught, so that it is clear whether the fishing effort was directed toward the catching of the species in question, or whether the average cited is merely of catches made incidental to the pursuit of another species. For example, the vessels seeking rosefish trawl exclusively in the deeper waters, around 70 to 100 fathoms. Only an occasional rosefish is taken in shallow water, and these fish are not caught in commercial quantities at medium depths. Therefore, a low catch of rosefish per unit of effort in shallow-water zones would not indicate a low abundance of rosefish in general. As another example, although the gray sole is taken to some extent at lesser depths, the bulk comes from certain types of bottom in the deeper water. The lemon sole, on the other hand, is abundant only in shallower areas. These differences in habitat have raised several problems of analysis, the solution of which is treated more fully below.

Another major problem is the study of the changes in the fishing fleet in respect both to numbers and to size and type of vessel, in order to gain a measure of the total fishing effort expended. For a great many years nearly all of the groundfish were taken with hook-and-line, but in the last 20 years there has grown up a huge and expanding otter-trawl fleet. At the same time, the number of line trawlers has gradually decreased until they are now a minor factor in the fishery. Changes in the vessels affect not only their efficiency in respect to their chosen type of gear but also their adaptability to other gears. Many vessels are so constructed that it is possible to shift to whatever gear is producing the greatest monetary reward at the moment. This adaptability means that there exists a great potential capacity to take any particular species. Although this capacity is seldom exercised to any great extent, owing to an economic balance, the ability to shift fishing effort from one species or fishing bank to another must be realized and fully considered before judging the effect upon any species of changes in the abundance of another.

The total catch during this period of expansion has remained at a high level, owing principally to two developments in addition to the increase in number and efficiency of the fishing vessels. One important factor in maintaining the poundage has been the shift to other species, such as the rosefish. From 1930–35, this species contributed

but 4,000,000 pounds a year, but in 1936–38 it averaged over 60,000,000 pounds. The rosefish is now sold throughout the Midwest and South as frozen fillets of "ocean perch." Another factor has been the increased dependence of the vessels on the banks off the Nova Scotian coast. Even if these banks can stand considerably more fishing, their distance from port means greatly increased cost of production. In the past few years there has been a great increase in the amount of trawling in deeper water, out to the 100-fathom curve and beyond, because of the demand for rosefish and gray sole. Since most of the available banks and most of the commercially abundant species are now being fished, it becomes increasingly clear that the future of this huge fishery depends upon utilizing the present banks and species to the best advantage.

The main problem then is to assess the three variables, total catch, fishing effort, and abundance, in order to determine for each species whether it can yield larger quantities or whether it has already reached the point where an increase in yield will give a larger production only at the expense of the future.

For this task the investigation has access to the following records: The poundages landed by species by each vessel for each trip from 1918 to date at Portland, Gloucester, and Boston (except for Boston landings at T Wharf) are available. For the vessels of over 50 gross tons, the actual weighed-out weights are given, but for the smaller vessels (5 net to 50 gross tons) the Boston records and some of the other records are hailed weights (i. e., estimates of the catch made by the captain when the trip is put up for sale at auction.) Since 1928, each slip also shows the type of gear the vessel employed in making the catch.

The record of the total annual catch by species of each fishing vessel (i. e., boat over 5 net tons) in New England since 1928 has been made available through the cooperation of the Division of Fishery Industries. These records are obtained by canvassing the fishermen themselves once a year to determine their catch. These records also show the gear used by each vessel, and, when more than one type is used, it shows the amount of each species caught by each type.

Since 1932, the haddock investigation has maintained a man at the Boston Fish Pier to interview the captain of each groundfish vessel, of over 50 gross tons, each time the vessel lands. These interviews give the day and hour of departure from and arrival at the pier, the locations fished by rectangles covering 10 minutes of latitude and 10 minutes of longitude, the depth fished, the proportion of the fishing time spent on each bank, and the proportion of the fish caught on each bank.

Analysis of abundance.—The methods used in analyzing these records for the haddock investigation are in general applicable to the groundfish analysis (which will in the future include the portion of the haddock investigation dealing with abundance), but had to undergo certain modifications on account of the tremendous mass of data to be handled and the differences in habits between the various species to be studied.

Through a project of the Works Progress Administration it was possible to obtain several needed assistants. The large accumulations

of catch-record receipts for the 21 years from 1918–1938 have all been sorted by month according to vessel and type of fishing gear, and filed so as to be readily accessible.

Using these records of landings in conjunction with the information obtained at Boston from interviews with fishing vessel captains, the relative abundance is being calculated for each species for the 7-year period 1932–38 from records of selected groups of otter trawlers. The procedure followed by the haddock investigation of subtracting running time of the vessel to and from the fishing banks, as well as time lost by bad weather, etc., in order to calculate the time spent in fishing on each bank, has been retained.

In order, however, to take care of the differences in the depth habitat of the various species, the banks have been divided into three depth zones, namely: Shallow, 0–30 fathoms; medium, 31–60 fathoms; and deep, over 60 fathoms. The allocation of catches into depth zones has been simplified by using the 10-minute unit area rectangles mentioned above.

The increased fishing for rosefish and gray sole in the deep zone within the past 3 years, the inauguration of depth zones, and the analysis of additional data concerning fishing grounds obtained since 1936, made it advisable to revise the statistical subarea boundaries in International Areas XXI and XXII. These were reoutlined on the basis of 39,632 days' fishing, in the various unit areas. Three subareas were eliminated from Area XXII by amalgamation and many minor adjustments were made in an attempt to simplify the analysis of the data by adjusting the boundary lines to the natural fishing concentrations. The handling of this large mass of data has been simplified by the use of cards which permits wide latitude in the grouping of areas or depths, and is invaluable in the assembling of the material for correlations.

The current analysis of these data, starting January 1, 1939, will be tabulated by the punch-card system that has been used for some years by the Bureau in the preparation of the monthly bulletin on the landings at Boston, Gloucester, and Portland by type of gear, species, and fishing bank. The punch card has been revised and the depth zone and calculated fishing time added to the information previously punched. Mr. Bearse interviews the vessel captains, and, by means of these interviews, supplies the Division of Fishery Industries' agent with these additional data. By this means it will be possible to obtain current data on abundance, which, despite its usefulness, is available for very few fisheries.

Total catch by areas.—A knowledge of the relative annual abundance does not permit any estimate of the productive capacity of a stock of fish without information on the total catch.

The landings of fishing vessels of over 5 net tons at Portland, Gloucester, and Boston (except for Boston landings at T Wharf) are shown both by type of gear used and by the subareas (fishing banks) where caught, in the monthly bulletin of the Division of Fishery Industries. However, these comprise but 65 percent of the New England groundfish landings.

The only records of total catch available for New England have been those of the Bureau's annual canvass; but, besides not being taken in some years, they cannot achieve a high degree of accuracy

because a large share of the individual fishermen from whom the estimates are obtained do not keep accurate records. In addition to this disadvantage, the annual canvass totals do not show either the season at which the catch was made, or the banks from which it was derived.

In cooperation with the Division of Fishery Industries and other members of the North Atlantic staff, an attempt has been made to encourage the New England States to install systems of collecting more complete and accurate statistics than those now available. One of the best systems for collecting such statistics is the use of triplicate receipt books by every fish buyer, so that a copy of each purchase showing the weighed-out poundage of every trip is available to the dealer, the fisherman, and the State. Such a system has been in use in California since 1915 and has been eminently successful.

The State of Maine inaugurated such a system on January 1, 1939, and the Bureau is aiding in getting it under way. Other New England States also are becoming more interested in obtaining better statistics of their fisheries, and the Bureau is encouraging and cooperating in the installation of such systems.

The fact that a fair share of the New England groundfish catch not landed at the three principal ports is caught in the inshore areas (as opposed to the large quantities from the offshore banks landed at the three ports) is shown by a preliminary analysis of the annual canvass vessel schedules which has revealed a large fleet of small vessels operating largely in shallow, inshore waters, and fishing primarily for flounders. These small flounder vessels are most numerous south of Cape Cod, although some land at Boston and Gloucester and along the coast of Maine. The catches of these smaller, inshore vessels will be analyzed by the flounder investigation as they will necessarily have to be correlated with the life-history findings.

Composition of the fishing fleet.—The fishing vessels have undergone many changes in size, power, and type. As explained above, these changes in the number and type of the fishing vessels must be known if one is to judge either the relative difference in annual fishing effort or the potential fishing effort that can be unleashed in any particular direction whenever economic conditions warrant. Furthermore, without knowledge of the total fishing effort, it is not safe to assume that the relative catch from year to year of a particular amount of fishing effort is not influenced by differences in the amount of competition with other vessels fishing the same grounds.

Since 1928, the weigh-out schedules for vessels landing at the three principal New England ports have given the type of gear used in making each catch. These data (available for over 700 vessels) are being analyzed to show the number of vessels of each size and type of gear that fished during each month over this period of 11 years. A preliminary tabulation of a few of the years during which New England annual canvass data are available, showed over 260 additional vessels that landed only at minor New England ports. These latter vesels were chiefly small inshore flounder trawlers and gill-net boats, although a few fair-sized vessels are included from Provincetown and New Bedford.

MIDDLE AND SOUTH ATLANTIC FISHERY INVESTIGATIONS

R. A. Nesbit, *in charge*

In Progress in Biological Inquiries for 1937 it was pointed out that the fisheries of the Middle and South Atlantic States offer an opportunity to benefit from scientifically controlled management. Increases in the amount of gear operated have diminished profits by increasing the cost of fishing and decreasing the yield. The problem of correcting excessive fishing and waste of small fish cannot be solved by individual fishermen. The responsibility rests on conservation officials, State and Federal, to advise fishermen what corrective measures they must support in their own interest.

The reduced abundance which has resulted from overfishing has also caused widespread dissatisfaction among anglers. Many of them, made impatient by the long delay in devising and adopting sound conservation measures, are advocating drastic curtailment and even elimination of commercial fishing for certain species. Legislation to this effect has been introduced in several State legislatures. Other anglers recognize that most marine species are capable, under sound management, of supporting a prosperous commercial fishery without detriment to angling interests, and are supporting the Bureau and State conservation organizations in their efforts to serve the common interests of commercial producers, anglers, and the consuming public.

The problem is twofold; to determine what measures are needed and practicable, and to provide for a unified or coordinated means of putting them into effect. The Council of State Governments is sponsoring a proposal to provide for the necessary cooperation in research and administration through an interstate advisory body created under the provisions of an interstate compact. Preliminary meetings were held during the year and a committee is preparing a draft of a compact for consideration by the several States and by Congress.

As in 1937, the courtesy of the University of Maryland in furnishing laboratory facilities at College Park, and of the Charleston Museum for similar accommodations in Charleston, S. C., is gratefully acknowledged.

SHORE FISHES

During 1938 the study of the shore fishes of the Middle Atlantic States was continued by William C. Neville. These investigations consisted principally of observations on the winter trawl fishery off the Virginia Capes, and cooperation with New York State in a biological survey of the marine fishes of Long Island.

Long Island Survey.—The Bureau participated in the Long Island Survey at the request of the New York State Conservation Department, acting principally in an advisory capacity. Mr. Neville, who was assigned as the Bureau's representative, spent most of the period from January to December on Long Island assisting the New York State biologists in the supervision and conduct of this work. Mr. Nesbit also served in an advisory capacity and Milton J. Lobell gave active support in certain phases of the study of the winter flounder. Mr. Neville assisted in the preparation and editing of a report on results of the survey, Mr. Nesbit preparing the section on squeteague

and Mr. Lobell that on the winter flounder. The Bureau assigned the *Phalarope II*, with Joseph Armstrong as engineer, from the Woods Hole, Mass., station to Long Island from May 1 to July 1. This boat was used in a survey of the young fish populations of the bays and inshore coastal waters of that region. Some scientific equipment and miscellaneous supplies were also furnished by the Bureau.

The main objectives of the Long Island survey were: (1) To provide information that could be used as a reliable basis for improving or maintaining good fishing insofar as the factors affecting the supply are controllable, and, (2) to determine by a census of fishing activities the recreational and commercial value of the marine district of Long Island to the citizens of New York State. Particular attention was given the winter flounder and squeteague because of the primary importance of these species to anglers and commercial fishermen. Other popular species as the fluke, striped bass, porgies, sea bass, tuna, and swordfish were given such study as 1 year's observations would permit. Fortunately, the information given by the 1938 survey is supplemented by results of similar study made by the Bureau during the past 10 years. Consequently, for some species, more definite conclusions could be drawn than otherwise would have been possible. Definite recommendations for the conservation of several species and for additional study of other species have been included in the report to be published by the New York Conservation Department.

Scup.—This species appears to be successfully withstanding the year-around activity of fishing which has resulted from the rise of the winter trawl fishery beginning about 1930, supplementing the summer fishery which has been operating on a large scale throughout the Middle Atlantic States since about 1900. Major fluctuations in the catch of scup have resulted more from variations in the success of reproduction than from fishing activities. A major increase in abundance occurred throughout the Middle Atlantic States beginning in 1929 and has continued in most of the subsequent years to date. This increase has been due largely to a series of successful spawning seasons beginning in 1927. Some waste of the supply is occurring because of prevailing fishing practices which permit the destruction of undersized and unmarketable sizes of fish. Correction of this abuse is difficult because the species is caught simultaneously with a variety of other fishes and by several different types of gear. Saving of scup by appropriate modifications of gear to insure the release of a large percentage of the small fish in good condition would probably involve a loss by gilling or escapement of marketable sizes of other kinds of fish of equal or greater value.

Progress on the report dealing with the causes of fluctuations in abundance of this species during the past years along the Middle Atlantic coast has been temporarily interrupted by Mr. Neville's assignment to the Long Island Survey. It is expected that this report will be completed during 1939.

Winter trawl fishery.—The year 1938 marked the seventh anniversary of the commencement of the winter trawl fishery off the Virginia Capes. Beginning about 1931, the fishery has expanded rapidly. The total catch of the principal fishes—namely, sea bass, fluke, porgies, and croakers—has risen from approximately 4,500,000 pounds in 1931 to over 19,000,000 pounds in the past few winters. The fleet has

increased from approximately 30 vessels in 1931 to over 125 vessels in 1938 and includes, in addition to local vessels, boats from New Jersey, New York, and Massachusetts. Landings are made mostly in Virginia and, to a lesser extent, in New Jersey and New York City.

The economic importance of this winter trawl fishery has increased since its beginning in 1931 through the creation of new market outlets for its production, particularly in the Southern States. This activity has also affected the distribution of numerous fishery products and introduced keen market competition with other distributing and production points, particularly in the Middle Atlantic States.

The activity of the winter trawl fishery is of biological significance in the probable effect it may have on the supply of those species that comprise its catch. To date there is no evidence that the winter fishery has caused any significant decline in the supply of scup. A reasonable doubt, however, exists as to whether the sea bass and fluke can withstand successfully the combined withdrawal of the winter and summer fisheries. Continued decreases in the catch per unit of effort for both species in most of the recent years and a similar reported decline in the summer fishery indicates a diminishing supply, probably from actual decreases in abundance. It is recognized that the winter trawl fishery may not be wholly responsible for this diminution in the catch but that the activity of the sport and commercial summer fisheries may also be contributing to the reported decline. A detailed study of fluke and sea bass, based on observations of the summer and winter fisheries, is therefore recommended to determine the cause of this decline and what corrections for restoring higher levels of abundance are necessary.

ANADROMOUS FISHES

Striped bass.—In 1938 two important reports dealing with the life history and conservation needs of this species were submitted for publication. Dr. Vadim D. Vladykov submitted to the Maryland Conservation Department a report on his investigation in Chesapeake Bay in 1936 and 1937, and Dr. Daniel Merriman submitted to the Bureau his report on studies begun in 1936 under the auspices of the Connecticut Board of Fisheries and Game, and continued in 1937 and 1938 with the cooperation of the Bureau and several Atlantic Coast States.

The following are the principal results of these studies: The striped bass is subject to year-class dominance. When successful spawning occurs, as it did in 1934 in Chesapeake Bay, not only are local stocks greatly augmented, but, as a result of migration, abundance is greatly increased along the coast from New Jersey to southern New England, and even in the Gulf of Maine. Since the large brood of 1934 was produced in a year when spawning adults were scarce, it is doubtful whether increased numbers of spawners should be the primary object of conservation measures. Catch records and studies of age composition of the catch indicate that the numbers of such successful broods diminish rapidly. For example, the 1934 year class yielded only about one-fourth as many fish in 1937 as in 1936. Tagging experiments indicated that the fishery accounts for most of the decline. Protection of striped bass until they reach a length of at least 16

inches, measured to the fork of the tail (approximately 17½ inches over all), would lead to greater yields and larger profits from each brood, whether large or small. The number of fish reaching spawning size would also be increased.

Shad.—In marked contrast to the striped bass, the principal problem in shad conservation is maintenance of an adequate spawning reserve. Although pollution and obstruction of rivers have doubtless contributed to failure of reproduction, the decline in yield of more than 80 percent during the present century has not been limited to polluted or obstructed streams. On the contrary, some almost unpolluted rivers, such as the Edisto River in South Carolina, have been severely depleted and a fine recovery has been observed in the polluted Hudson River. This recovery is attributed to regulations limiting fishing to 4 nights a week and closing spawning areas to fishing.

In order to extend to other localities the benefits of the experience in the Hudson it is necessary to know the approximate spawning escapement there and to devise means of matching it substantially elsewhere.

Studies in 1938 indicate that the fishery removed somewhat more than 50 percent of the run. Of 196 shad tagged in Sandy Hook Bay in April, 53 percent were taken during the season in the river. Since tagging experiments usually underestimate fishing intensity it is probable that the fishery removed somewhat more than the indicated percentage.

As a check on the estimate of fishing mortality by tagging experiments, scales were examined for spawning marks in 1938 to estimate the percentage of that year's catch contributed by fish which had escaped the fishery in 1937. On the basis of the reported catch in 1937, and assuming a fishing mortality of 60 percent, approximately 1,667,000 fish should have entered the river in 1937. Of these, about 1,000,000 were caught and 667,000 escaped. Assuming 10 percent mortality among these after they left the river, about 600,000 would be expected to return in 1938. From preliminary estimates of the catch in 1938 it appears that the total run to the river was about 1,250,000 fish. Of these about 600,000, or 48 percent, would be "repeaters" or fish which had escaped the fishery and which had spawned in 1937. Forty-six percent of the scales collected in 1938 bore spawning marks indicating that they had spawned in 1937, certainly in very good agreement with the expectation from the above estimate.

Similar collections of scales have been made in other rivers where depletion is greater. As might be expected, the percentage of scales having spawning marks is much lower, but, until records of the catch for 1937 and 1938 are available, the percentage escapement in 1937 cannot be estimated.

Because of the importance of reproduction in shad conservation a careful ecological study of the early life history is being made by John C. Pearson and Louella Cable. In 1938 intensive work was done in the Edisto River in South Carolina and it is expected that these studies will be extended to other rivers in 1939. In these studies especial attention is being paid to estimating rates of mortality at various stages in the early life history, at various levels of abundance of young, and under various conditions of temperature and volume

of river flow. For example, in 1938 most of the eggs taken in the plankton were dead. This may merely represent oversampling of the surface levels, for all plankton collections were made by surface nets. Further observations will be made in 1939 using bottom nets.

Such observations are expected to be of great value in estimating the optimum spawning escapement and also as a basis for estimating the most suitable size for releasing young shad produced in hatcheries.

Mr. Pearson conducted experiments in rearing shad fry in bass ponds at the Edenton, N. C., and the Orangeburg, S. C., Hatcheries. At the former station 6,500 young shad grew to a mean length of 35 mm. (1⅜ inches) in 35 days in April and early May. The pond was drained and an attempt made to rear a second lot in the same pond. Only 500 fish survived. It is not known whether this was the result of diminished food production during the summer or to the activities of predators accidentally introduced.

As a working hypothesis for the shad investigation, it has been assumed that the majority of the shad return to the river in which they were spawned. The correctness of this assumption is being tested from several angles. The tagging experiments which were intended primarily to measure fishing intensity will also indicate whether adult shad seek the same river each time they spawn. (Five shad have been recaptured, after a lapse of a year, in the same river or in estuaries en route.) Vertebral counts of adult shad are being compared with those of juveniles taken in connection with the early life history studies. The scales of adult shad from each of several rivers are being compared with those of young shad. Marked differences have been noted in the size and appearance of the stream-growth portion of the scales from different rivers, but until data from other years are available it cannot be determined whether these differences are characteristic of each year's brood in the individual streams. Attempts to tag juveniles have been unsuccessful thus far, but further experiments are planned.

SHRIMP INVESTIGATIONS

MILTON J. LINDNER, *in charge*

With an annual catch averaging well over 100,000,000 pounds, the shrimp fishery is the most important marine food resource of the South Atlantic and Gulf States. The Shrimp Investigations are designed to provide a thorough knowledge of the life history, migrations, ecological relationships, and abundance of this first-ranking marine organism of the Southern States as a basis for its intelligent conservation.

All the members of the scientific staff which, in addition to Mr. Lindner, includes William W. Anderson and C. Howard Baltzo, have been associated at different times during the year with each of the various field investigations undertaken. In addition to the Bureau employees, Albert Collier, Marine Biologist of the Texas Game, Fish, and Oyster Commission, has been actively engaged in conducting a cooperative research program in Texas under the general direction of Mr. Lindner. The Louisiana Department of Conservation has continued to furnish office and laboratory space in New Orleans for the headquarters of the investigation. In October,

Commissioner Rankin, of the Louisiana Department of Conservation, kindly arranged to supply more spacious quarters for the staff and collections at 336 Chartres St., New Orleans, La. The city of Gulfport, Miss., has continued to furnish dockage space for the *Pelican* and a storage room for equipment. Arrangements have been made with Dr. A. E. Parr, of Yale University, for analyses of the water samples, and with Dr. Dana Russell, of Louisiana State University, for analyses of the bottom core and mud samples taken during the cruises of the *Pelican*.

In the course of the shrimp investigations, which have been under way since 1931, it has been found that the common shrimp spawns during the spring and summer in the open waters of the Atlantic Ocean and the Gulf of Mexico. The eggs are not carried by the female but are extruded directly into the water. The young enter the inland waters at an early stage in their development. The extensive inland water areas of the South are the nursery grounds of the shrimp, where the young feed and grow. Those young not successful in reaching the nursery grounds perish. As the immature shrimp increase in size they gradually leave the nursery grounds and return to the ocean. The growth rate of the shrimp is quite rapid, and by mid-June or July, depending upon the locality, the young are of sufficient size to appear in the commercial fishery. By September, practically the entire catch is composed of these immature shrimp, for the adults disappear from the fishery as spawning progresses. Sexual maturity is attained in 1 year. The movements and behavior of the shrimp are affected by temperature, salinity, and tides.

Tagging experiments have demonstrated that shrimp are migratory. During the fall and winter the larger shrimp move south along the Atlantic coast from North Carolina, South Carolina, and Georgia into the waters off the coast of central Florida. In several instances tagged individuals have been picked up more than 300 miles from the place of release. The smaller shrimp, however, tend to remain in local waters and are not subject to such extensive movements.

In the Gulf of Mexico it was suspected that the larger shrimp, from the Louisiana coast at least, move off into deeper waters during the winter. With a suitable vessel and the proper equipment it was considered highly probable that a new winter fishery could be developed off the Louisiana coast. The *Pelican* was transferred to the Shrimp Investigations in 1937 for this purpose, but, owing to lack of funds, operation of the boat was deferred until January 1938.

The major program of work undertaken during the year falls into three general categories, namely: Offshore scouting operations with the *Pelican* in the Gulf of Mexico, tagging experiments along the Atlantic coast and the Louisiana coast, and ecological studies in Texas.

OFFSHORE OPERATIONS

Among the results of the 1938 investigations, the event of outstanding importance to the commercial fishery was the discovery of a winter concentration area for large shrimp off the central Louisiana coast. The *Pelican* began operations in January and operated continuously until June, when the loss of the trawling cable necessitated

a lay-up of 1 month for replacement. The boat was again placed in operation in July, but was laid up for engine repairs and for the duration of the dangerous hurricane season from August through October. Operations were resumed for a short period in November.

The offshore area from Mobile, Ala., 60 miles north of Brownsville, Tex., was covered with the *Pelican.* In this region 402 trawl hauls were taken and 96 hydrographic stations were occupied. From each haul observations were made on the quantity, sex, length, and gonad development of the shrimp. At the hydrographic stations temperature and salinity observations were secured for various depths, and core-tube and Petersen grab samples were obtained for study of the types of bottom and organisms present. Trawling was done in depths up to 180 fathoms. It developed during the course of the work that a small 9-foot trawl, towed at full speed, was admirably suited for scouting. As much as 8 gallons of shrimp have been taken with this gear in a half-hour haul.

That a winter concentration point for the larger common shrimp occurs off the Louisiana coast, in the region between Ship Shoal Buoy and Trinity Shoal Buoy, is quite evident from the data collected with the *Pelican.* As a result of the discovery of this area by the Bureau, boats operating from Morgan City, La., initiated a commercial fishery based on this offshore group of shrimp. A number of the Florida shrimp boats, which are better suited for offshore operations than the smaller and less seaworthy Louisiana craft, have migrated to Morgan City and Berwick, La., and have developed this fishery to one of considerable magnitude.

No shrimp concentrations of any significant size were found between the Alabama coast and the mouth of the Mississippi River. Off Texas during April the common shrimp appeared to be scattered about the 10-fathom contour, but with no evident heavy aggregations. The less-abundant grooved shrimp was found in depths up to 70 fathoms but no commercial concentrations were encountered.

Inasmuch as a considerable amount of offshore work remains to be done in the Gulf, it is planned to continue these operations during 1939. The region between Mobile, Ala., and St. Marks, Fla., should be covered to determine the depth distribution of shrimp in this area and whether or not commercial concentrations occur. The Texas coast should be scouted as far south as the Mexican border during midwinter. The fishing grounds between Ship and Trinity Shoals should be covered at regular intervals during the spring, summer, and early fall to determine: (1) The extent and duration of the apparent onshore movement of the common shrimp during spring and early summer; (2) the fate of the adult spawning shrimp as the season progresses; (3) the magnitude of and the period covered by spawning; and (4) the time that the young shrimp begin to appear in this area after leaving the bays.

TAGGING EXPERIMENTS

For several years tagging experiments designed to provide information on migrations, growth rate, fishing intensity, and fate of the adult shrimp have been in progress throughout the South Atlantic shrimp fishing areas. Understanding of the fishery in this section depends largely upon the solution of these problems.

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Previous tagging had established the fact that the larger shrimp move south along the coast during winter, concentrating in the waters between St. Augustine and Cape Canaveral, Fla. Indications of a return northward movement had been obtained from length-frequency distributions and prior tagging. Conclusive evidence, however, of this return movement had not been secured.

During 1938, 3,160 tagged shrimp were released from Cape Canaveral to St. Augustine in January, February, and March, a period representing the height and decline of the Florida winter fishery. From releases at Cape Canaveral returns were secured as far north as Fripp Island, S. C., a distance of some 250 miles. It is therefore evident that a return movement does occur. Whether this return movement is made at random or represents the return of shrimp to the region where they originated has not yet been determined.

Although the larger shrimp migrate to the southward during the winter, the small individuals remain in the local waters of Georgia. In January, February, and early March, 1,325 shrimp from this group were tagged and released in the area around Brunswick, Ga., in an effort to determine whether they also are migratory. The returns indicate that this class does not undertake any extensive movements. Additional tagging experiments in various areas along the entire coast would add materially to our knowledge of this group of so-called "local shrimp."

From April through August 3,200 tagged shrimp were released in the vicinity of Brunswick. The returns from these releases indicate that no extensive coastwise migrations were occurring at this season.

Because of the extensive and continuous migrations and movements of the shrimp, growth determinations by length-frequency distributions cannot be relied upon to present a true picture of the rate of growth over any considerable period of time. Neither can study of growth of confined individuals represent the true growth rate, owning to the extreme difficulty or impossibility of duplicating the widely varied changes in habitat that the shrimp undergo as they increase in size. Tagging experiments, therefore, provide the best source of information on the growth of the shrimp in its natural environment, as each shrimp is measured at release and upon recapture. Although many data have been accumulated, more tagging is required to arrive at an accurate approximation of the growth rate of shrimp during the different seasons of the year, and in different localities.

The determination of fishing intensity has long been a difficult problem. Although the percentage of returns from tagging experiments gives some indication of fishing intensity, detailed and accurate catch statistics are also necessary. None of the States in the area covered by the shrimp fishery has gathered catch statistics in a form suitable for analysis of the shrimp population density, a situation which is particularly deplorable in view of the magnitude of the fishery. Because of the lack of funds, personnel, and regulatory authority, it has been impossible for the shrimp staff to secure the necessary statistics. A serious effort was made during the year to secure voluntary cooperation of the fishermen in keeping daily catch records. Log books were provided to all boat captains willing to

maintain them. Results indicate that a venture of this nature can be successful only through frequent personal contacts with the men keeping the logs. One shrimp cannery in Georgia kindly allowed the transcription of its entire boat catch records from 1921 to 1937. These records, which were copied in 1938, should be of considerable value in tracing the progress of the central Georgia shrimp fishery during its period of most rapid development.

It is quite evident from the work done so far that if adult shrimp survive for 2 or more years in any quantities along the Atlantic coast, they must move into deeper offshore areas beyond the range of the present commercial fishery. This important information which is lacking in our knowledge of the life-history of the common shrimp can only be determined by thorough scouting of the offshore waters between Cape Hatteras and Cape Canaveral. Exact knowledge, which is not now available, of the depth distribution of the shrimp along the Atlantic coast during the spawning season is of particular importance in attempting to delimit the spawning areas. Tentative plans are being made for the use of the *Pelican* on the Atlantic coast after the completion of the Gulf survey.

The expansion of the offshore fishery in the Gulf has raised the important question of whether these shrimp are of local origin or whether they are migrants from other States. It was deemed advisable, because of the urgent need for knowledge of the movements of shrimp in the Gulf, to suspend activities at the Brunswick (Ga.) station in the fall and transfer *Launch 58* to New Orleans for tagging operations. The first of the Louisiana tagging experiments was inaugurated during December, when 2,300 shrimp were released between the Mississippi River and Ship Shoal. The objective of these experiments, which should be extended to cover the entire fishery, is to determine the migrations, growth, age, and fishing intensity of the Gulf shrimp. Tagging will be continued during the coming year as funds permit.

ECOLOGICAL STUDIES

The Texas Investigation is operated on a cooperative basis with the Coastal Division of the Texas Game, Fish and Oyster Commission. With the transfer of Kenneth H. Mosher to the Pacific Pilchard Investigations, the sampling of the commercial catch at Aransas Pass was discontinued. Albert Collier, of the Texas Commission, has conducted studies during the year to determine the relationship between the environmental changes and the distribution of shrimp in Aransas Bay. What effects do temperature, salinity, tides, currents, and food have on the reactions of the shrimp in its natural habitat? What determines the time when young shrimp leave the shoaler nursery grounds for Aransas Bay and later for the Gulf? Why does the success of the commercial catch fluctuate so greatly from day to day? Can these fluctuations be determined in advance? Is there actually a definite distribution pattern of shrimp in Aransas Bay, as appears to be the case from the commercial catch, and if such a distribution is present what is the cause? These and many other problems require solution for a better understanding and wiser utilization of the shrimp supply.

Stations were established at various points in Aransas and Copano Bays. These stations were occupied at regular weekly intervals when the weather and availability of boats permitted. At each station trawl hauls were made for shrimp, and temperature and salinity observations were taken. In the fall Mr. Collier instituted a weekly survey of the shrimp distribution in Aransas Bay. Hauls of 5 minutes duration were made with a small trawl in closely spaced parallel lines across the bay. From this work it appears that the shrimp follow a rather well-defined path across Aransas Bay in their movements from the more interior nursery grounds to the Gulf. During the coming year efforts will be directed toward determining the fundamental reasons for this distribution.

NORTH PACIFIC AND ALASKA FISHERY INVESTIGATIONS

DR. F. A. DAVIDSON, *in charge*

The North Pacific and Alaska Fishery Investigations, with headquarters in the Fisheries Biological Station at Seattle, Wash., are concerned chiefly with the maintenance and rehabilitation of the salmon and herring fisheries of Alaska and the salmon fisheries of Puget Sound and the Columbia River. All of the major investigations in progress in 1937 were continued in 1938 with the exception of the Puget Sound sockeye investigation, which was discontinued in March 1938. An investigation of the Bristol Bay fisheries was undertaken in July 1938.

COLUMBIA RIVER SALMON FISHERIES

Investigations of the Columbia River salmon fisheries were continued during 1938 by J. A. Craig, A. J. Suomela, M. J. Hanavan, Z. E. Parkhurst, J. L. Wilding, W. M. Morton, and J. A. Coleman.

Stream surveys.—One of the factors contributing to the depletion of salmon runs in the Columbia River watershed is the fact that important spawning grounds have been rendered inaccessible or made unsuitable for migratory fishes by the construction of irrigation diversions and by other activities of man. With the primary purpose of classifying those areas which may be rehabilitated, and of discovering means of making them accessible to fishes, an extensive stream-survey program has been undertaken and is now well under way.

During the early part of the season these stream-survey activities were centered in the Willamette River system. In this area surveys were completed on the McKenzie River, the middle and coast forks of the Willamette and Long Tom Rivers, and the upper portions of the North and South Forks of the Santiam. The Clackamas River survey was partially completed. The McKenzie, Middle Willamette, and the Santiam Rivers are the most important spring chinook streams of the Willamette system.

The Payette River system in Idaho was surveyed during the month of August. In early years this river was one of the important salmon streams in Idaho. Chinook and blueback salmon and steelhead trout migrated to the headwaters of this river in large numbers.

Payette Lake, at the headwaters of the North Fork, is reported to have supported a run of blueback salmon. Dams without adequate fish protection are responsible to a great extent for the extinction of the salmon runs in this river. A dam constructed at Horseshoe Bend 30 years ago probably destroyed the blueback run which had entered Payette Lake, and limited the migration of chinooks and steelheads to the part of the river below this obstruction. In 1925 the Black Canyon Dam was constructed by the United States Reclamation Service. This dam is a complete barrier to all migratory fish, since no fish protection was provided. It is reported that there have been fewer salmon observed below the dam each year. The stream survey revealed that the amount of favorable spawning area in the Payette River system is great enough to provide facilities for a large run of fish, if access to the spawning grounds were provided.

Stream surveys were carried on in 258 miles of the Clearwater River, including the main river from the mouth to Kamiah Creek, Potlatch Creek, North Fork to Kelly Creek, Middle Fork, Sellway River to Meadow Creek, and the Lochsa to Fire Creek. Some 500 miles of this large river system remain to be examined.

Stream surveys were also started on the Klickitat River but only 38 miles had been surveyed when winter weather conditions forced the termination of the survey for the season.

A total of 1,177 miles of stream was surveyed during the season. Information obtained from these surveys was made available to various interested agencies.

Salmon redds and spawning habits.—An investigation was undertaken to study the spawning habits of spring and fall chinook, silver, and chum salmon as an aid in interpreting the results of the stream survey. The information gained as a result of this investigation is as follows: (1) The space required for each pair of spawning fish, (2) type of gravel selected, (3) depth of water preferred, and (4) temperature prevailing at the time of spawning. In addition, case histories of individual redds were recorded, including data on the longitudinal and horizontal measurements of the redds, the time of the male intervention, the deposition of the ova, and superimposition and succession of the redds. These studies were conducted in the Kalama, Ohanopecosh, Toutle, Grays, German, Abernathy, and Alochaman Rivers.

During the period of investigation information was obtained on 486 salmon redds in these rivers. The results of this study are now being analyzed and a report for publication will be submitted in the near future.

Tagging.—A series of 25 tagging experiments were conducted in the Columbia River on spring and fall chinooks which pass through the fishery from May 1 to the latter part of August and early September. The purpose of these experiments is to obtain data on (1) the rate of migration of the salmon upstream, (2) their distribution in the river system, (3) their appearance at hatcheries, and (4) some estimate of fishing mortality. These experiments will contribute invaluable information as a basis for regulation of the fishery and for stocking policies.

The experiments were carried out at three localities on the river, Sand Island, Woody Island, and in the vicinity of Oak Point. These

points are located 5, 25, and 45 miles, respectively, from the mouth of the Columbia.

During these operations 2,357 chinooks were tagged and liberated, of which 743, or 31.5 percent, were recovered from the commercial fishery, sport fishery, hatchery, and from the spawning grounds. The recovery from hatcheries was 48 tags, or 2.04 percent.

Information was obtained on the distribution of the spring chinook run in the tributaries of the Columbia, indicating that fish entering the river in the month of May are destined for tributaries in the Upper Columbia, Snake River, and Willamette River systems.

The results of this experiment will be included in a report which is being prepared for publication.

Construction of fish protective works.—On the 1st of July combination grants of P. W. A. and W. P. A. funds were made available for the construction of fish screens and other fish-protection works on certain Federal power and irrigation projects. These allotments authorized the expenditure of $50,000 in each of the States of Oregon, Washington, and Idaho, and $118,000 for the construction of one fish screen in the Wapato Canal of the United States Indian Service near Yakima, Wash., and one screen in the power canal of the United States Reclamation Service near Prosser, Wash. Surveys have been made and plans drawn for screens at the Wapato Canal, Prosser Canal, and Black Canyon Dam diversion of the Reclamation Service in Idaho, remodeling of screens in the Sunnyside Canal near Yakima, Wash., and construction of a screen in the Echo Feed Canal of the Reclamation Service on the Umatilla River in Oregon, as well as for several small projects in the State of Washington. Contracts have been let and work started on the construction of the steel screen drums for the above-mentioned projects. A contract has been made and work is well advanced on the concrete structure for the Wapato Canal screens. Excavation work has been going forward at the Black Canyon Dam site and at the Sunnyside Canal and considerable concrete and steel work has been done as well at Sunnyside. Concrete structures will be built at the remaining sites when the work can be done at the lowest cost and with the least interference with canal operations. This work has been done under the supervision of J. A. Craig and O. W. Lindgren, associate hydraulic engineer.

Special surveys.—An observer was stationed at the dam across the Clearwater River at Lewiston, Idaho, from late spring until late fall to observe the condition of the runs of migratory fish passing that point. It was found that a significant run of steelhead trout still enters the stream, but that salmon are no longer numerous in that watershed. Lack of adequate fishways is apparently the reason for this condition and the owners of the dam have drawn plans for two new fishways and the remodeling of the present single structure. As soon as this construction is completed, several hundred miles of spawning grounds will be made available again to salmon. Collection and tabulation of statistical data relating to catch records and abundance of salmon and steelheads of the river were continued.

COHO SALMON

The coho salmon investigation, the basic objectives of which are a study of the life history of this species under the varying conditions

found in the different streams of the Puget Sound region, the determination of the causes for the decline in its abundance, and the development of methods for rebuilding the runs was continued during the past year by George B. Kelez.

The series of three marking experiments undertaken during the fall and winter of 1937 at the Quilcene (Wash.) station of the Division of Fish Culture [2] was completed, during the month of May, with the marking of 17,094 coho fingerlings of the 1936 brood. These fish had been held for the purpose of releasing them at the approximate time of normal seaward migration. At the time of this last release, marked individuals from the lots released in September and December 1937 could still be observed in the Quilcene River in the vicinity of the hatchery. It is expected that comparative returns from these experiments will provide further information both on the success of various periods of hatchery rearing and on the relation of the additional costs of prolonged rearing to the increased survival rate of the fingerlings liberated.

No further recoveries of marked fish from the 1935 experiment on Voights Creek, tributary to the Puyallup River, were made during the late winter run, and none were taken from the Green River.[2]

Several tags from the 1937 Samish River experiment were returned to the laboratory during the spring and summer. This experiment was undertaken to test the practicability of marking fingerlings by the use of an internal celluloid tag in combination with the excision of the dorsal fin, as an alternative to the usual method of marking in which two or more fins are removed. If this method is successful, it will eliminate the present limitation on the number of possible experiments which the number of available fin combinations imposes.

Collections of scale samples and biological data from mature cohos taken in the commercial fishery were made during the season. Samples aggregating approximately 4,500 fish were taken during the summer fishery at Anacortes, Wash., and samples of more than 2,000 fish were taken during the fall fishery at Seattle. Supplementary samples and catch data were collected during the season from the sport fishery carried on in the vicinity of Seattle. Collections of coho fingerlings were also taken during the season from the sport fishery carried on in the vicinity of Seattle and the major streams tributary to Puget Sound.

During the spawning migration regular collections of scale samples were taken and estimates of population size were made on all streams tributary to Puget Sound on the eastern shore. It is believed that variations in early life history, as shown by the scale nucleii, will differ sufficiently between the colder northern streams and the warmer southern ones to afford a means of separating these populations on the basis of scale characteristics. Through a comparison of samples of scales taken from the commercial fishery with those from the two spawning areas, the relative contribution of these districts to the fishery may be determined.

Observations on the spawning grounds during the fall and early winter indicate that, although the total escapement of cohos was not large this year, spawners were well distributed in all the streams of the region.

[2] See "Progress in Biological Inquiries, 1937."

BRISTOL BAY SALMON FISHERIES

The Bristol Bay region of Alaska is the greatest red-salmon producing area in the world, providing, as it does, more than 60,000,000 pounds of first quality canned salmon a year. Sporadic studies of the salmon in this area have been carried on since 1922, and information has been obtained on the age and migration habits of some of the populations inhabiting the five major watersheds in this region.

The recent development of extensive offshore fishing has been considered a possible source of serious injury to this salmon fishery. The fact that there is little available knowledge of the life history of salmon in this area, and of the factors affecting the survival of the populations as a whole, made it imperative to inaugurate a thorough biological study of the fish of this region, their migration routes and the factors affecting their survival. An appropriation was made available on July 1 for the purpose of carrying on the first year's study of a 5-year program of investigation. The problems entailed in such an investigation are manifold and must necessarily include studies of a multitude of factors, biological, physical, and chemical, affecting the species from the time the eggs are deposited in the gravels in the upper reaches of the watersheds until the progeny from one year's spawning have completed their life cycle and have deposited the fertilized eggs from which another brood will result.

The investigation separates itself into two distinct though related divisions, the fresh-water and the marine, which are being carried on by George B. Kelez and J. T. Barnaby, respectively.

Fresh-water studies.—The principal activities of this phase of the investigation consist of the determination of the physical and biological characteristics of the fresh-water areas of the Bristol Bay region, the evaluation of the annual spawning populations, age analyses of the runs in the various rivers, and the measurement of factors influencing the mortality of the eggs and young fish in fresh water.

During the past season reconnaissance surveys of the five main river systems of the region were made, in which the general topographical features of the watersheds, the number and size of the headwater lakes and tributary streams, and the extent of the spawning areas were noted. From these observations thorough surveys of important spawning grounds have been planned and areas selected for carrying on marking experiments, migrant collections, and similar studies.

A number of small lakes, typical of the particular watersheds in which they lie, were inspected, and several suitable ones chosen for studies of the biological characteristics of the environment in which the young fish grow and develop. Here, also, the effect of varying climatic conditions on the survival of the stocks may be determined.

Methods of handling the commercial catch at the canneries were observed and plans were made for a complete annual program of random sampling of the catch in which scale samples will be taken for age analysis. Data on size, weight, and sex ratio will be obtained for population studies. These collections will be supplemented by similar sampling on the spawning grounds of each river system. From this material the age-group composition of each year's run, the

total return from each season's spawning brood, and the selective effects of the commercial fishery may be determined.

Marine studies.—The sockeye salmon, after migrating seaward, spend 2 or 3 years in the ocean and then return to fresh water to spawn. During this period they make over 98 percent of their growth in weight. Hence, environmental factors affecting the fish during their stay in salt water have a most important part in determining the condition and quality of the mature fish.

The United States Coast Guard very generously cooperated with the investigation by furnishing one of their large cutters, the *Redwing*, for the purpose of conducting an oceanographic survey of the waters of Bristol Bay and the contiguous waters in which salmon live during their ocean sojourn.

The program of oceanographic studies followed the general methods used by Dr. T. G. Thompson, Director of the Oceanographic Laboratories at the University of Washington, who has been making oceanographic studies of the North Pacific Ocean for a number of years. In this way the data will be in proper form for comparison with the results of the general survey.

During the season the entire area of Bristol Bay proper, comprising over 10,000 square miles, was crossed and recrossed and samples were collected at 164 stations. The oxygen and salinity content of the water were determined and temperature data collected for the purpose of calculating the direction and force of the ocean currents. As a corollary to these studies current meters were operated at various depths and data were collected on the type of bottom and the depth of water at each station. Plankton samples were collected to determine the type and abundance of food present for the fish.

The oceanographic surveys are to be continued and the migration routes of the fish are to be determined by extensive marking, tagging, and sampling programs. These data will also furnish information on the fluctuations in ocean mortality.

KARLUK RIVER RED SALMON

The investigation to determine the extent and causes of the fluctuations in the size of red salmon runs in Karluk River, Alaska, was continued in 1938 by J. T. Barnaby and Allan C. DeLacy. Field work was carried on from early April until the end of September.

Population studies.—The commercial catch of Karluk red salmon was sampled throughout the season to discover marked fish returning from marking experiments carried out in previous years. During the season 305,283 salmon were examined and 1,481 marked fish were found. The purpose of these experiments is to determine the mortality of the fish during their stay in the ocean. The results to date indicate that ocean mortality is fairly constant and that the variations in the ratio of return to escapement are mainly due to fluctuations in the environmental conditions affecting the fish during their stay in fresh water. The returns of marked fish during the past season were mainly from the experiments of 1936, in which year 26,700 fingerlings were marked by excision of the adipose and right ventral fins and 26,700 by excision of the adipose and both ventrals. Thus, in addition to the basic information desired, these experiments

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served as a check on the relative value of the different marks used. Recoveries of fish in which only one ventral had been removed amounted to 663, while recoveries of the fish in which both ventrals had been removed totaled only 569. Apparently the fish marked by removal of the adipose and both ventrals had a lower survival value than did the other group. While complete returns from this experiment will not be at hand until 1940 these results indicate that caution should be exercised in comparing marking experiments in which different combinations of fins have been removed.

A counting weir was again operated in the Karluk River to determine the number of fish going up the river to the spawning grounds. Counting was continued until September 3, at which time 875,678 red salmon and 1,639,589 pink salmon had passed upstream. Owing to the large number of dead spawned-out pink salmon drifting downstream the weir had to be removed on September 4. While the escapement figures are consequently not quite complete, they are of considerable value. Data on the escapements and the returns from given escapements have been collected for a number of years and it is important that no breaks should occur in the series of data.

More than 11,500 scale samples were collected during the season for the purpose of calculating the age group composition of the escapement and the commercial catch. The number of fish returning from each brood year is determined in this way and credited to the proper year. This study is of basic importance because it indicates what variations may be expected in the returns from known escapements and what is the optimum sized escapement for this and other watersheds of a similar magnitude and nature.

Ovaries from fish ranging in size from 20 to 24 inches were preserved and counts are being made to determine the number of eggs produced by each fish. The results of the present investigation will be compared with similar work done in 1926 to determine whether or not any change is taking place in the fecundity of the species.

The seaward migration of red salmon fingerlings began on May 26 and continued intermittently until June 16. For the purpose of determining the age composition and the length frequency of the various age groups making up the migration, samples were collected on all days the migrants were in the river. The migration appeared to be of average magnitude and the fingerlings were of the usual strong, sturdy stock so characteristic of this watershed.

Predatory species.—As the char *Salvelinus malma*, or Dolly Varden trout, is very abundant in the Karluk watershed and is considered to be one of the most important salmon predators, a study of this species is being carried on in conjunction with the studies of the salmon population. In 1937 a series of marking and tagging experiments were initiated to aid in determining the size, homogeneity, growth rate, migration habits, and mortality of the population of chars inhabiting the Karluk River and Karluk Lake. During the past year three more experiments were started, in which external tags were used in lieu of the internal tags used in the 1937 experiments. To recover the internal tags and discover the distinguishing number it was necessary to kill and dissect the fish. The external tag has a marked advantage in that a recaptured tagged fish can be identified by the number on the tag, measured, and then released. Recaptures of chars from these experiments are conse-

quently expected to extend over several years, permitting accurate determination of growth and longevity of the species.

The results obtained from the 1937 and 1938 tagging experiments show that: (1) There is a slight amount of straying from one watershed to another but on the whole the chars return in the fall to the same streams from which they entered the ocean. (2) Many, if not all, of the chars that migrate seaward in the spring, return to fresh water in the fall of the same year and migrate seaward again in the spring of the following year. (3) There are at least two populations of chars in the Karluk watershed, those that live in Karluk Lake and those that live in the river. However, these populations mix to some extent. (4) The chars in Karluk Lake do not comprise a homogeneous population but are apparently divided into several rather distinct groups which intermingle to a slight degree. (5) The chars in this watershed have a relatively slow growth and are relatively long lived. (6) Sea-run chars make a faster growth during the time they are in the ocean than do the non-sea-run type during the same period of time. (7) Sea-run chars, on the average, make no growth in the 8- to 9-month period spent in fresh water between the upstream migration of one year and the downstream migration of the following year. Length-weight measurements made in the spring, and again in the fall, have shown that there is a marked difference in the condition factor of the downstream and upstream migrating chars. During the few months spent in the ocean these fish increase in weight from 60 to 100 percent, and about two-thirds of this weight increase is lost between the time of the upstream migration of one fall and the time of the downstream migration of the following spring. This loss in weight is attributable to the fact that these fish spawn during the period spent in fresh water and also in part to the limited food supply available during the winter months.

A cooperative observer's meteorological station was installed at Karluk in the latter part of June 1937. Data for the first fiscal year were complete by June 30, 1938. The collection of these data is of considerable importance in view of the marked effect climatic conditions have on the survival of salmon. The average monthly rainfall was 2.77 inches, the total for the fiscal year being 33.26 inches. There were 110 clear days and 255 cloudy or partly cloudy days. There was precipitation on 149 days. The highest air temperature during the year was 66° F. and the lowest was 6° F. The yearly mean average was 40.3° F.

PINK SALMON

The pink-salmon investigation during 1938 dealt with the factors contributing to the change in abundance and the time of appearance of the pink-salmon runs in Southeastern Alaska. This investigation was carried on by Dr. F. A. Davidson and Samuel J. Hutchinson. The work was confined to a study of the pink-salmon runs in Southeastern Alaska which comprise the bulk of the Alaska pink-salmon catches. The total 1938 catch fell below previous yearly packs and, according to all indications, the runs are maintaining themselves with difficulty under the intensive commercial fishery. If the condition of the runs is not improved in the very near future, drastic measures will have to be taken to rehabilitate these salmon populations or they will soon fall to a dangerously low level of abundance.

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1937. From these figures it would appear that the run has been able to maintain itself at a more or less fixed level of abundance in this locality during the past 5 years.

After the adult salmon had entered the stream to spawn, a series of gravel samples were taken from 28 nests of spawning fish to determine the size and type of rubble selected. In computing a percentage mean for each gravel size, and using all of the samples, it was found that 6.38 percent was 3-inch gravel or over; 5.79 percent was 2½-inch gravel; 8.38 percent was 2-inch; 10.80 percent was 1½-inch; 14.82 percent was 1-inch; 7.57 percent was ¾-inch; 12.75 percent was ½-inch; 8.76 percent was ¼-inch; and 24.76 percent was sand aggregate that passed through a ¼-inch screen. Nesting areas composed of gravel over 3 inches in diameter are not selected when areas of the finer aggregate are available, but, owing to crowded conditions, nest building and spawning sometimes take place in large rubble.

In February 1938, a C. C. C. camp was moved from Juneau, Alaska, to Little Port Walter, under the supervision of the Forest Service. C. C. C. personnel worked at the station all spring and summer clearing ground, building a dock and float, moving buildings to higher ground, constructing 3 miles of forest trail, and building two shelter cabins on the headwater lakes at Little Port Walter.

On July 22 and 24 the Forest Service, Bureau of Fisheries, and C. C. C. personnel cooperated on an experimental trout planting program through the use of aeroplanes. Rainbow trout averaging 10 inches in length were flown from Sashin Lake, back of Little Port Walter, to Blue Lake near Sitka. Other plantings were flown to a number of lakes south of Red Bluff on Baranof Island. The C. C. C. camp completed its program at Little Port Walter by the first of September and was moved to Port Alexander.

The cooperative observer's meteorological records were continued during 1938 at Little Port Walter. Through these records it is possible to measure the climatic changes that have a direct effect on the salmon's fresh-water environment. An anemometer and a psychrometer were installed as additional equipment to measure wind and humidity which indirectly play a part in the salmon's life cycle. A total of 264.53 inches of rain fell during 1938 at Little Port Walter, which is an average of 22.04 inches per month. Rain was recorded on 261 days. The highest air temperature was 71° F., and the lowest was 13° F., with a yearly mean average of 43.08° F. Fifty-five clear days, 58 partly cloudy, and 252 cloudy days were recorded at the station during 1938.

ALASKA SALMON STATISTICS

Collection, tabulation, and analysis of the daily catch records from the various types of fishing gear operated by the salmon fishery in Alaska were continued in 1938 by Elizabeth Vaughan. All available catch records have been collected, and the files will be kept up to date in the future.

Analysis of these data consists mainly in determining average daily catches for each type of gear throughout each fishing season by districts. Indices of abundance and seasonal time of appearance of the salmon runs are determined from these daily averages. During the past year, the trap-catch records for 1937 in both Prince William Sound and Southeastern Alaska were analyzed and added to the previous compilations. This information, as in the past, was used as a basis for recommending changes in the fishing regulations in Alaska in order to provide for the conservation of the salmon resources. During the past year the gill-net records from the Bristol Bay area have been compiled for all years for which data are available.

From practically all parts of Alaska, fishermen and cannerymen have reported that pink salmon were very late in appearing during the 1938 season. It was felt that this phenomenon was unusual in all areas except Southeastern Alaska, where it was claimed the runs have been steadily getting later. Because of this belief, the industry demanded a revision of the fishing regulations. The statistics of the fishery, as collected and analyzed by this investigation, permitted an explanation of this phenomenon and a defense of the present regulations, which were embodied in a series of articles for publication in a commercial fishery journal.

The explanation of the change in the time of appearance of the Southeastern Alaska pink-salmon runs was made on the basis of the correlation between the abundance of the salmon, their average size, and the time of their appearance in the season.

HERRING

Investigation of the herring fisheries of Alaska was continued in 1938 by E. H. Dahlgren. Mr. Kolloen, who was assigned as a permanent assistant in this work beginning in July, carried out the field work of catch-record collection and of obtaining data on the size and age composition of the populations in the Kodiak and Prince William Sound areas during the season.

Previous tagging experiments have established the fact that, while the herring populations of Southeastern Alaska are divided into a series of separate populations, there are certain areas, notably at Warren Channel and at the west coast of Kuiu Island, where two of the major populations intermingle on the feeding grounds. The electronic detector was operated to search the fish taken for frozen bait from the Sitka spawning area during the spring. Only two tags were recovered, owing to the decline in the age class which had supported the fishery for the previous 4 years. The younger fish, which were available to the bait fishermen this spring, had not been available for tagging during the previous seasons. Nevertheless, the recovery of these two tags, affixed in previous years at this spawning area, definitely established the fact that the herring return to the same grounds year after year to spawn.

A controlled tagging experiment was carried on at the station at Little Port Walter in order to determine the maximum size of tag which a herring may carry without causing undue mortality. If it is proven that a tag of considerably increased mass can be carried, the difficulty of recovery will be greatly reduced. After an initial heavy mortality the herring appear to survive with a minimum of loss. However, the mortality increases in direct ratio to size of tag, with the largest tag showing an 87 percent mortality as compared to 34 percent for the smallest and 20 percent for the controls at the end of a 2-month period. The experiment is being continued through the winter with the watchman maintaining the records.

The Southeastern fishery declined to an all-time low since its great expansion in 1927. Since that year the fishery has depended, in some seasons almost exclusively, on the population which spawns in the vicinity of Sitka and which migrates during the summer to Cape Ommaney to support that fishery, and to Warren Island and the west coast of Kuiu Island, where it mingles with the population which spawns at Craig. Studies of the age composition of this population show the almost total failure of three successive brood years; that of 1932, 1933, and 1934. These failures, together with a too intensive fishery, caused a decline of this stock to a dangerously low level.

The measure used in evaluating the abundance of this population is a comparison of the catch per unit of gear per day's fishing, with the average catch per day's fishing established over a 9-year period. In deriving these indices the fleet has been divided into two groups (those of over 35 net tons and those under this capacity) to minimize the difference in efficiency of the larger and smaller vessels. The index for the 1938 season for the large vessels was 35, as compared to 71 for 1937 and 140 for the optimum season of 1932. The indices for the smaller vessels were 41 for 1938 as compared to 75 for 1937 and 164 for the optimum 1932 season. On the basis of these findings,

a closure of the Cape Ommaney area was recommended until the population shows definite signs of rehabilitation. The dangerously low level to which this population has been reduced was further evidenced by the failure of the normal number of spawners to appear at the Sitka area, which usually has had a large area heavily spawned.

The fishery in the Prince William Sound and Kodiak areas continues at a high level of abundance, as shown by continuing high yield and large catches per unit of gear. These areas are not yet as intensively fished as is Southeastern Alaska, but considerable expansion is contemplated in each area, and a close watch must be maintained to avoid over-exploitation and consequent depletion.

PACIFIC PILCHARD INVESTIGATIONS

O. E. Sette, *in charge*

After 6 years of rapid and sustained increase in the total yield, the Pacific coast pilchard fishery experienced sharp fluctuations between 1937 and 1939. The season of 1937–38, for example, ended with a catch of 415,583 tons, which was 36 percent less than had been taken the previous year. In Washington and Oregon, on the other hand, though the summer season of 1938 was shorter than that of 1937, the total catch was greater than in any previous year, being 40,000 tons, or about 18 percent more than in 1937. Likewise, the fall season of 1938–39 in California was relatively successful, yielding by the end of 1938 a catch of 530,452 tons, which was 61 percent higher than that of the corresponding period of the previous year. Though other fluctuations had occurred during the relatively short history of the pilchard fishery, the sharp drop of last year's catch, following as it did an intensification of the fishery, caused concern among many as to the state of abundance of the pilchard stock. That there are fluctuations in the availability and even abundance of the stock, however, is one of the many elements that makes the problem of appraising the condition of the pilchard resource so elusive and complex.

This is a problem on which several organizations have been working for a number of years, namely, the fish commissions of California, Oregon, Washington, and British Columbia. In October 1937, the United States Bureau of Fisheries established a laboratory at Stanford University to cooperate with these agencies, to assist in the coordination of their results, and to investigate those features needed to supplement their findings. In May 1938, a conference of biologists, representing all the institutions working on pilchard research, was held at Stanford University. Past and current investigations were discussed and plans laid for future work.

Up to the end of 1937, a considerable body of information had been collected bearing on the migrations, spawning, age, and growth of the pilchard. Tagging experiments have demonstrated extensive migrations along the coast for as great a distance as between California and British Columbia. The spawning season has been determined in California, the principal spawning grounds surveyed, and the egg and larval stages described. The phenomenon of fluctuating year classes has been well established, individual dominant year classes having been recognized and traced through several years.

The basic problem remaining for solution is this: What is the optimum level of catch below which the stock would go to waste through underutilization, above which it would become reduced to commercial unimportance through overexploitation? Before this level can be determined, three questions must be solved: (1) How much is the stock reduced by the fishing? (2) How has the relation in the stock of income to outgo changed during the growth of the fishery? (3) How much does fishing in specific areas affect the stock in other areas?

Answering these questions necessitates the determination of abundance, age, reproductive success, and of the importance of intermigration. These necessities determined the program of the South Pacific Investigations during 1938.

STUDIES OF ABUNDANCE

Since the conventional method of estimating abundance from the performance of fishing fleets is limited to the range of fishing operations, attempts were made to measure directly the size of the pilchard population by aerial observations. This work, done in planes of the United States Navy and Coast Guard from January to May, covered an aggregate of 13,000 miles of flying distance, extending from Cape San Quentin on the south to Santa Barbara on the north, and several hundred miles to sea, and covering the more important schooling grounds of the pilchard a number of times. Although schools were sighted frequently and identified as pilchards, it was found to be unfeasible to estimate their size because their limits could not be defined. Also, judging from the time and places of occurrence, it was concluded that they did not appear near the surface by day in proportion to their abundance. Night observations were even less satisfactory, and the aerial method had to be abandoned.

Consequently, a measurement of changes in relative abundance by an analysis of the commercial catch, begun in 1937, took on added importance. The catches of boats delivering pilchards to the floating reduction plants, operating off San Francisco since 1931, were made available for this purpose by the plant owners; and the shore landings of the fleet considered were furnished by the California State Fisheries Laboratory.

Obviously, the boat catches alone are not directly indicative of the availability or abundance of the fish, for the activities and success of fishing boats are modified by the weather, the number of hours of darkness, since pilchard fishing is carried on in California only in the dark, and by other less tangible influences. Consequently, it was necessary to treat the data statistically so as to account, as far as possible, for the effects of these influences. Transcription of the records was completed and the analysis was under way during 1938. It is anticipated that a report on this subject will be completed in 1939. The findings in relation to comparable work being carried on for the ports of Monterey and San Pedro by the California State Fisheries Laboratory, and for Oregon and Washington by the Fish Commission of Oregon, should answer question 1.

AGE AND GROWTH

The second question can be answered by determining the ages of the fish making up the population each year, thus learning the relative abundance of the individual broods of previous years (income) and how fast they are removed by fishing and by natural mortality (outgo). To begin with, the relationship between age and size must be established. Once that is done, the findings can be applied to past records to detect any changes in the balance between income and outgo.

Age determination is being attempted by interpreting marks in hard structures, by observing the growth of young pilchards, and by identifying modes in frequency distributions of the adult population. During 1938, a series of frequency curves of young fish measured in southern California was collected, from which the growth rates of the first two or three age classes may be traced. A sample of young was also collected for comparative purposes at Magdalena Bay, Lower California, and others from Coos Bay, Oreg., and from various points in Washington.

Scales and otoliths were collected through the year from the young fish samples. Most of these, numbering over 10,000, have already been mounted by a W. P. A. project, and they are now being studied to learn the time of appearance of a year-mark and the extent to which pilchard scales can be used for age determination. During 1938, sampling of young fish was carried on at San Pedro, Newport Beach, and San Diego. This work will be continued in 1939 so as to complete at least one year's cycle of growth.

For studies on various phases of the biology of the commercial-sized fish, the South Pacific staff sampled the catch at Grays Harbor during the summer at Washington, and during the subsequent fall and winter at San Francisco. In addition to age and growth studies by analysis of the frequency curves, these data will be examined to determine the extent to which the populations of the two regions can be identified with each other. The work will be much facilitated by comparable samples from Oregon, taken by the Oregon Fish Commission.

A history of the size composition of the pilchard population in California, going back almost to the beginning of the fishery, has been kept by the California State Fisheries Laboratory, whose staff has sampled the catch systematically since 1919. Thus is recorded the rise, growth, and decline of the various dominant year classes that have appeared since then. This vast amount of data is being made available to the South Pacific Investigations for use in connection with current studies. During the year part of these records have been transcribed to a punch-card sort system. Through the aid of a W. P. A. project, it is expected that the remainder of the transcription will be completed during 1939. The records will be treated statistically in an effort to recognize homologous component age groups, to measure the rate of their removal, and hence to compare the effect of the lower fishing intensities of former years with higher current intensities.

EARLY LIFE HISTORY

The study of the data on size composition has already shown a relation between temperature and incoming successful year classes, warm years being associated with their appearance in the fishery 3 years later, cold years with their nonappearance. A report on this subject was prepared during 1938 for publication.

Further investigation of the relation between temperature, or other environmental elements, and successful year classes should make it possible to predict 3 years in advance the relative size of year classes, and hence facilitate greatly an intelligent management of the fishery from the conservation as well as industrial viewpoint.

Such knowledge requires a boat for the quantitative sampling of the young during their stages of random distribution, and for the study of conditions on the actual spawning and nursery grounds. For 1939, arrangements have been made with the Scripps Institution of Oceanography for a joint expedition on the research boat *E. W. Scripps* during May and June off the coast from California to British Columbia. The northern and western limits of the spawning range of the pilchard will be sought by the Bureau. Parallel observations on the hydrographic conditions will be made by Scripps Institution. This first cruise must of necessity be of a preliminary nature, and can be of far-reaching significance only when related to cruises made in other years and covering the entire pilchard-spawning season. It seems unlikely that such a program of marine work can be carried out unless a boat is at the year-round disposal of the investigation.

ORIGIN OF THE COMMERCIAL SUPPLY

To determine whether the stock in northern waters is self-perpetuating, young pilchards were sought along the Washington and Oregon coasts during the year. The stomachs of salmon and albacore, both predaceous, which presumably feed to some extent on pilchards, were examined at frequent intervals between March and December. In this manner young fish were found in April and, later, additional ones were collected by a beach seine in Willapa Bay, and others in a trap at Coos Bay. Though these collections may indicate some spawning in northern waters, the importance of such spawning in perpetuating the population found there is yet to be investigated.

It is hoped to appraise the contributions from various spawning areas through study of the sculpturing on the scales. Preliminary examination has shown that the spacing of the ridges on scales appears to differ among young fish caught in different localities. If further work confirms preliminary observations, this would be a characteristic established early and preserved throughout life. It would constitute, in effect, a marking on the fish according to areas of origin, and suitable interpretation of it would provide an answer to question 3. This will require additional collections of young fish during 1939 in various localities from Mexico to British Columbia. The studies on the scales will be continued so as to determine the significance and utility of ridge measurements and age determinations.

The program of work was carried out by a staff consisting of O. E. Sette, in charge of the investigations, Dr. L. A. Walford,

Kenneth Mosher, Ralph Silliman, and Earl Palmer. The prosecution of these investigations over so large an area was made possible by the cooperation and assistance of several organizations and persons. Stanford University contributed spacious laboratories for the central office, and extended the privileges of the University to staff members. The California Institute of Technology provided space for the southern field station at its marine laboratory in Corona del Mar. The California State Fisheries Laboratory furnished records essential to various phases of the work. Various branches of the Government service gave much valuable cooperation during the year. The aerial observations were carried on in planes of the United States Navy and Coast Guard. Space was provided a member of the Bureau on board the United States Coast Guard Cutter *Hermes* for experimental work on collecting apparatus at sea and for a cruise to Magdalena Bay, where samples of young fish were obtained. Also, the Coast Guard, as well as the United States Weather Bureau, furnished weather data for points along the Pacific coast. During the year the staff enjoyed the advice of members of these organizations, particularly of Drs. Frank W. Weymouth, Willis H. Rich, and Hugh H. Skilling of Stanford University, and Lt. Comdr. C. W. Thomas and Lts. S. C. Linholm and W. E. Sinton of the United States Coast Guard. The extensive sampling of the catch was made possible by the willing cooperation of members of the fishing industry from San Diego to Seattle.

GREAT LAKES FISHERY INVESTIGATIONS

Dr. John Van Oosten, *in charge*

The critical depletion of the more valuable commercial species continues to be the major problem of the Great Lakes fisheries. The extent of this depletion is apparent from comparison of the present-day production of certain species with that of earlier years. As an illustration, if normal production in Lake Michigan is given an index value of 100, the present productions of important species are as follows: Wall-eyed pike, 62; lake herring, 59; lake trout, 58; whitefish, 58; yellow perch, 43. Similarly, the production indexes of perch and chubs in Lake Huron are only 44 and 36, respectively, and the production of the renowned Lake Superior whitefish is only 10 percent of normal. The preceding examples are only representative; in Lake Erie the production of nearly all important commercial species is without question on the decline, and the present total production of Lake Ontario is only 20 percent of normal.

The downward trend in the production and abundance of important commercial species of the Great Lakes has by no means reached its limit, except, of course, for such forms as the sturgeon, the Lake Ontario bloater, the blackfin of Lakes Michigan and Huron, the bluefin and longjaw of Lake Superior, and the Lake Erie cisco, all of which have become commercially unimportant. With most species, present conditions represent only a stage in a process of depletion that will certainly lead to the complete ruin of the fishery unless immediate and drastic measures are taken to halt present abuses.

As proof of the contention that depletion is even now proceeding rapidly, it may be pointed out that trout fishermen of Lake Superior

have found it most difficult to operate at a profit during the past 2 seasons; that the production of whitefish in Lake Michigan dropped to an all-time low in 1936 and failed to show significant improvement in 1937; that the production of chubs in the State of Michigan waters of Lake Michigan decreased more than 40 percent from 1935 to 1937; that the 1937 production of whitefish in Lake Huron was only 1,120,000 pounds as compared to a 1930–34 average of 3,394,000 pounds; and, finally, that the production of yellow perch in Lake Erie decreased from 14,219,000 pounds in 1934 to 2,051,000 pounds in 1936. It is true that the production of some species has at times shown temporary improvement, but these increases have merely constituted irregularities in the general downward trend.

Decades of bitter experience have demonstrated conclusively that the depletion of Great Lakes fishes cannot be halted under the present system of divided control, in which each State frames its own laws for the regulation of the fisheries within its boundaries.

The possibility that adequate and uniform regulations for Great Lakes fisheries will ultimately be attained was increased greatly in 1938 by the active support of two influential organizations, the Council of State Governments and the National Resources Committee. At a Great Lakes Fisheries Conference called by the Council at Detroit February 25–26, 1938, a resolution was adopted recommending the establishment, by treaty with Canada, of an International Board of Inquiry into conditions of the Great Lakes fisheries. A Special Committee on Lake Michigan Fisheries was organized and held its first meeting at the time of the Great Lakes Conference. The Special Committee held a second meeting in Chicago on May 6.

Both the Great Lakes Committee and the Special Committee on Lake Michigan Fisheries held meetings in the late autumn in Chicago, at which time they reviewed progress made during the year and elaborated their program for coordinated action by Canadian, Federal, and State agencies. As an immediate goal both committees will attempt to secure the enactment of discretionary power acts whereby the conservation departments of the several Great Lakes States will be authorized to regulate Great Lakes Fisheries by executive order.

The appointment of Dr. Van Oosten in October 1938, to membership in the Water Resources Committees, of the National Resources Committee, of the Upper Great Lakes (Superior, Michigan, and Huron) and Lake Erie basins marked the first representation of Great Lake fisheries interests on these committees. Dr. Van Oosten was later made a member of a subcommittee of each of the basin committees on water as related to industry and navigation. The Upper Great Lakes and Lake Erie Basin Committees plan to cooperate fully with all agencies interested in the development of a sound conservation program for Great Lakes fisheries.

An executive order drawn up by the Wisconsin Conservation Commission and signed by the Governor on January 21, 1938, constituted an outstanding advance in the regulation of Great Lakes fisheries. The order contained provisions for substantial increases in the mesh size of commercial gear and in the size limits of lake trout and whitefish in the Lake Michigan waters of the State. These changes, which brought the Wisconsin regulations nearer the standards maintained by the State of Michigan, are an important step toward the attainment of uniform regulations for all Lake Michigan waters.

The activities of the Great Lakes staff were again characterized by active cooperation with State and Federal officials and with sport and commercial fishermen. Certain of the cooperative projects will be described later in this report. During the year Dr. Van Oosten acted in an advisory capacity at 19 meetings and conferences in which Great Lakes fisheries problems were under consideration. He also continued to assist State conservation officials in the drafting of proposed fisheries regulations.

The Bureau gratefully acknowledges the cooperation of the University of Michigan in providing laboratory space and extending numerous other courtesies to the staff.

STUDIES OF ABUNDANCE

Dr. Ralph Hile has completed the routine computation of 1937 indexes of production, abundance, and fishing intensity for important commercial species in each of the 20 statistical districts of the State of Michigan waters of the Great Lakes. The assignment of a W. P. A. project to the Great Lakes laboratories has made possible the tabulation of valuable production statistics for the several fishing districts over the 18-year period, 1891–1908. These compilations are being made from original records loaned to the Bureau by the Michigan Department of Conservation.

AGE AND GROWTH STUDIES

Lake Huron whitefish.—A study (in press) of the Lake Huron whitefish, *Coregonus clupeaformis*, by Dr. Van Oosten included information on growth rate, growth compensation, the age and year-class composition of the stock, the sex ratio, age at maturity, the relationship of total and standard length, the length-weight relationship, and the coefficient of condition. The Lake Huron whitefish grows most rapidly in the first year of life, but a secondary period of rapid growth occurs in the fourth year. Growth compensation occurs during at least the first 7 years of life. The collection of the summer of 1923 was dominated by age-group IV (1919-year class), and the fall collection of 1924 was dominated by age-group VI (1918-year class). The sexes were equally abundant in the collections as a whole, although the males tended to become relatively less numerous with increase in age. Sexual maturity was attained by nearly all males in the fifth year and by females in the seventh year. A single curve was found suitable to express the length-weight relationship of both males and females. There was, nevertheless, a noticeable tendency for females to be heavier than males of the same length, and for whitefish taken in the summer of 1923 to be in better condition than those collected in the fall of 1924.

Lake Champlain whitefish.—A paper entitled "The Age, Growth, and Food of the Whitefish of Lake Champlain" by Drs. Van Oosten and Deason is now in press. The materials consisted of scale samples and records of weights and measurements of 120 whitefish taken in northern Lake Champlain in 1930, and 175 individuals taken in southern Lake Champlain in 1931, and of the stomachs of 141 whitefish, also collected from southern Lake Champlain during the fall of 1931. The data suggested that the natural size and age compo-

sition of the Missisquoi Bay population was disturbed by the early fall seining of 1930. The size and age distribution of the southern Lake Champlain fish indicated that no disturbance through exploitation had taken place. The two populations were more or less distinct also as to growth rate, the length-weight relationship, and the location of spawning grounds. Autumn is apparently a season of reduced feeding activity, for 86 percent of the 141 stomachs examined were empty. The food consisted almost exclusively of invertebrates (99.1 percent) which were made up principally of mollusks (92.8 percent).

Lake Erie yellow perch.—Mr. Jobes has completed the preliminary draft of a manuscript on the growth of the Lake Erie perch. Much of the information obtained in this study has been presented in past reports. The most important new development was the determination of a method for the calculation of growth from scale measurements. Lengths at the end of the second and later years can be computed by direct proportion, that is, on the assumption that the body-scale ratio is constant. First-year lengths, however, must be determined from an empirical curve of the body-scale relationship.

SPECIAL SURVEYS

Red Lakes and the International Lakes.—At the request of the Office of Indian Affairs of the Department of the Interior, Drs. Van Oosten and H. J. Deason conducted a 3-week survey of the fisheries of Upper and Lower Red Lakes in northern Minnesota during late August and early September 1938. The principal purpose of the investigation was to obtain information for the settlement of various controversies concerning the regulation of the commercial gill-net fishery that is conducted by the Indians on Lower Red Lake and by white citizens on Upper Red Lake. The survey included the quantitative analysis of commercial catches as to species and size composition, a study of the variations in the size of gill-net mesh employed, and the collection of biological data for the study of the life histories of the principal species. All available statistical records of the commercial fishery and of the artificial propagation of wall-eyed pike and whitefish were transcribed for later analysis. Conservation and Indian Agency officials, fishermen, and other interested persons were interviewed.

A large portion of the work preparatory to the submission of a formal report has been completed. The report will contain recommendations, largely for the guidance of officials of the Red Lake Indian Agency, for the regulation of the commercial fisheries which constitute one of the principal sources of income for the Indians.

Following the Red Lakes survey Dr. Van Oosten made a brief survey of the boundary waters of northern Minnesota and southwestern Ontario, at which time he interviewed fishermen, transcribed statistical records, and collected biological data on the principal commercial species.

Potagannissing Bay investigation.—The investigation of the relationship between the sport and commercial fisheries of Potagannissing Bay, Lake Huron, conducted under the joint supervision of Dr. Van Oosten and F. A. Westerman of the Michigan Department of Conservation, has been concluded and a formal report has been pre-

pared. The allegedly harmful effect of the commercial trap-net fishery of the area on the population of game fishes, particularly smallmouth bass, in the region apparently has been overestimated. The occurrence of large numbers of bass in the trap nets is distinctly seasonal and confined to relatively limited areas. Consequently, only minor restrictions on the commercial fishery for coarse fish are necessary in order to afford adequate protection to the game-fish stock. The report contains specific recommendations for the regulation of the fisheries.

Lake Champlain investigation.—The report of the International Fact-Finding Commission, consisting of Dr. Van Oosten of the Bureau and of James A. Rodd of the Department of Marine and Fisheries, Ottawa, Ontario, on fisheries controversies on Lake Champlain was largely completed during the past year and will soon be submitted to the respective governments. The report will contain a discussion of the fisheries controversies, a tabulation and analysis of all available information concerning commercial fishing and angling, descriptions of the natural history of the principal species, a critical historical review of the artificial propagation of wall-eyed pike and yellow perch, and recommendations for the regulation of the commercial and sport fisheries of Lake Champlain. Appendices to the report will contain original studies of the feeding habits of the principal species as independent contributions of Dr. H. J. Deason and F. W. Jobes of the Bureau, and Dr. R. H. M'Gonigle of the Fisheries Research Board of Canada.

SHELLFISH INVESTIGATIONS

Dr. Paul S. Galtsoff, *in charge*

Although the difficulties experienced by the oyster industry in past years were greatly alleviated during 1938 by the general improvement of economic conditions in the country, the decreasing supply of good oysters continued to present a serious problem endangering the future progress of the industry. Scientific and technical knowledge concerning the oyster and its method of cultivation shows that this difficulty can be overcome by increased cultivation of oysters, improvement of the quality of oyster meat, and standardization of the raw and canned product offered to the consumer.

Practical application of this principle meets, however, with many legal and technical difficulties. In many States the introduction of oyster-cultural methods on a large scale necessitates the reorganization of existing policies and systems of operation and abandonment of the practice of exploiting natural oyster resources. Personnel capable of directing and supervising oyster-cultural activities is required to introduce systems of cultivation into States where exploitation of the public bottoms has been the traditional method of the oyster industry since its establishment. Inasmuch as the development of methods of oyster culture suited to the varying conditions of local waters depends upon scientific studies of the physiology and life history of the oyster, it is apparent that the accumulation and dissemination of such information among interested persons is of great practical importance to the oyster industry.

Studies on the propagation of the oyster, its cultivation on public and privately owned bottoms, and the protection of valuable fishing

areas against the attacks of natural enemies and pollution have continued to be the principal fields of shellfish investigation conducted by the Bureau in Massachusetts, Connecticut, Virginia, North Carolina, South Carolina, and Florida.

To determine the practicability of various methods of oyster culture suggested by laboratory experiments, steps have been taken to establish experimental oyster beds in localities set aside for this purpose by State authorities. In cooperation with the South Carolina Board of Fisheries and the Works Progress Administration an experimental project of this nature was undertaken in South Carolina. Experiments on the control of starfish were conducted in Long Island Sound and studies of the parasites of the oyster were continued in Beaufort, N. C. The work on pulp-mill pollution in York River was continued with the cooperation of the Virginia Department of Fisheries with the view of determining the chemical nature of the substance present in the effluent which was shown by previous investigation to be harmful to oysters.

PHYSIOLOGY OF THE OYSTER

Propagation.—Since successful propagation depends upon the presence on oyster beds of a large number of specimens of both sexes capable of spawning, the sex changes in the adult oyster present a problem of practical importance to the oyster farmer. Study of this problem was continued by Dr. Galtsoff and staff at the Woods Hole (Mass.) laboratory and at Milford, Conn., where experimental mollusks individually marked are kept in the outdoor tanks. During the first year (1937) 8.0 percent of the males changed to females and 13.1 percent of the females changed to males, total change in either direction being 9.7 percent. In the second year (1938) 11.2 percent of the males changed to females and 12.1 percent of the females became males, total percentage of changes in either direction being 11.5. Sex reversal among oysters that have already changed their sex occurs much more often. Out of the total of 32 oysters which changed their sex at any time between 1936 and 1938, 22 (69 percent) reversed their sex. The results suggest the presence in the population of a group of animals with unstable gonads.

Development of spawning reactions, which are different in the two sexes and are characterized in females by the rhythmicity of muscular contractions and discharge of eggs through the gills, fails sometimes to keep pace with gonadal changes and results in physiological intersexuality. Some of the sex-reversed males, possessing ripe ovaries, reacted in typically male fashion by discharging eggs through the cloaca. A complete female spawning reaction occurred, however, at the end of the reproductive season, at which time the intersexuality had disappeared.

Survival and aging of eggs and sperm.—Experiments on fertilizability of eggs and their survival in water after being discharged by the oyster were carried out at Woods Hole by Dr. Galtsoff. It has been found that more than 50 percent of the eggs will cleave if sperm is added after 12 hours, but a very small percentage cleave normally if 24 hours elapse between their discharge and insemination. The life of sperm depends to a certain extent upon its concentration in sea water. In sufficient concentration (0.2 g. in 50 ml. of sea

water) good sperm is still effective after 24 hours. In greater dilution the sperm perishes sooner. These experiments indicate that simultaneous spawning of the majority of adult specimens and crowding of spawners on spawning beds are essential for the successful propagation of the oyster.

Respiration.—The study of oyster respiration was undertaken with the view of determining the effect of environmental conditions on this fundamental living process. An understanding of the factors controlling the uptake of oxygen by an aquatic mollusk is especially necessary for the study of its carbohydrate metabolism and of other metabolic processes which result in the accumulation of glycogen, heavy metals, calcium, and other elements which, from the nutritive point of view, are important food constituents of the oyster meat.

Using the metabolism chamber specially designed for this work and employing the technique perfected during the previous summer, Dr. Galtsoff and G. I. Mishtowt carried out a number of experiments studying the effect of lowered salinity and increased CO_2 tension on oxygen consumption. It has been found that in all the experiments with diluted sea water the oyster used an average of 13.6 percent more oxygen in a salinity of 24 parts per thousand than in a salinity of 32.

Experiments with CO_2 consisted in bubbling this gas through sea water and determining the rate of oxygen consumption. It was found that CO_2 has a depressive effect on oxygen consumption, which begins to decrease with the decrease of hydrogen ion concentration. The maximum effect is obtained at pH 6.0 or lower, the oyster under these conditions using practically no oxygen and presenting all the appearances of being narcotized.

Further plans for this investigation comprise the determination of respiratory quotients of oysters at different times of the year and under various environmental conditions, and a study of the effect of various pollutants on respiration.

OYSTER CULTURAL STUDIES

Propagation of oysters in Long Island Sound.—The oyster industry of Long Island Sound and adjacent waters depends upon an abundant supply of seed oysters for its perpetuation. Since the rate of survival of Connecticut seed oysters transplanted to other waters is high, and their growth in a new environment is rapid, there is always an extensive demand for them, and seed producing has become a profitable industry of the State. However, owing to the frequent failure of oysters to set, the industry has not been in a position to supply the much needed seed oysters. In addition to the poor natural setting, the destruction of spat and seed oysters by various pests, especially starfish, is tremendous. The protection of young oysters from their enemies constitutes, therefore, another vital problem for the oystermen. Both problems have been under investigation by Dr. V. L. Loosanoff and James B. Engle at the Fisheries Laboratory at Milford, Conn.

Spawning and setting.—Continuing the investigations begun in 1937, spawning and setting of oysters were observed at a chain of 15 stations extending from Bridgeport to Morgan Point and east to New Haven, thus covering the most important part of the Connecti-

cut seed-oyster producing section. The methods employed in this study were identical with those used the previous year.

Observations of the past 2 summers on the spawning of oysters in Long Island Sound indicate that, contrary to common belief, spawning may take place at temperatures several degrees lower than 20° C. (68.5° F.). The first spawning of oysters occurred on June 28, far in advance of the expected time and at a temperature of only 16.4° C. (62° F.). The highest temperature recorded on this day at any of our sampling stations, distributed over a distance of 30 miles of the oyster-producing section of the Sound, was 18.3° C. (66° F.). The average bottom-water temperature of all 15 stations was 17° C. (63° F.). To avoid any errors in recording the water temperature, measurements were taken simultaneously with four deep-sea reversing thermometers, their correctness was verified by the United States Bureau of Standards, and the temperature was read by two investigators.

These observations indicate the need for modifying previous methods for predicting the time of spawning which have been based upon the assumption that oysters do not spawn at a temperature below 20° C. It is evident that other factors, undetermined at present, are involved in inducing the spawning of oysters at low temperatures. Until these factors and their role in stimulating the shedding of sex cells is ascertained, no infallible method for predicting the spawning time of oysters living under natural conditions can be advanced.

Throughout the summer systematic observations on the setting of oyster larvae were made at some 37 stations located in different sections of the Connecticut oyster-growing area. In general the setting occurred late and was extremely light. During the course of these surveys information on the condition of oysters and the prospects of obtaining set was supplied to oystermen at regular intervals through a bulletin distributed by the Connecticut Shellfish Commission.

Observations on vertical distribution of oyster set in 1938 fully support conclusions reached during the previous year to the effect that in Milford Harbor setting occurs in the zone extending from the bottom to a point 2 or 3 feet above low-water mark. Above this level to high-water mark, a distance of about 4 or 5 feet, no setting occurs.

Chemical control of starfish.—A method for the control of starfish by chemical means was tested during the year in large-scale experiments in the Long Island Sound area. Early results of these field experiments and of previous laboratory tests indicate that important progress has been made toward effecting the control of the most important enemy of the oyster in the New England area.

Since mechanical control of starfish on oyster beds is expensive and only partially effective, the advantages of employing some toxic substance for the eradication of these pests have been obvious. Laboratory experiments on the use of calcium oxide, or quicklime, for the destruction of starfish were therefore initiated at the Milford Laboratory in 1937 by Dr. Loosanoff and Mr. Engle. During the spring and summer of 1938 the method was also tested under natural conditions on the oyster beds of Long Island Sound, where starfish are abundant.

In one test where 25 acres of starfish-infested oyster bottom were treated with calcium oxide at the rate of 480 pounds per acre, as many as 80 percent of the starfish were found to be affected by the chemical 1 week after the beginning of the experiment. In an area where 280 pounds of calcium oxide per acre were used, the chemical acted upon 74 percent of the starfish. It is believed that much better results will be achieved when a suitable mechanical method insuring uniformity of distribution of the chemical over the treated area has been developed.

Observations in the Milford Laboratory show that the particles of lime must come into direct contact with the body of the starfish to be effective. Particles of the chemical falling on the upper surface of the starfish imbed themselves in the delicate skin and rapidly cause its disintegration through caustic action. Lesions so created rapidly increase in size, spreading in all directions and involving the delicate respiratory and other structures found on the dorsal surface of the starfish. After several days the lesions penetrate the body wall, exposing the internal organs. Death usually follows very shortly. Starfish which are not hit by falling particles as the chemical is being applied may eventually come into contact with it by crawling on the bottom. Lime spread on the bottom retains its effectiveness for some time.

Laboratory experiments conducted in large tide-filling concrete tanks indicated that coarse grades of lime, even when used at the rate of 3 barrels (840 pounds) per acre, do not cover the bottom evenly but permit many starfish to escape. Finely powdered lime was found to be much more effective, even in concentrations as light as 280 pounds per acre.

To determine the effect of quicklime on other animals, experiments were carried out with oysters, flatfish, and lobsters, which support the most important fisheries in Long Island Sound.

Oysters which were subjected for a period of 5½ months to a very strong concentration of quicklime survived, although their growth and increase in weight were somewhat retarded. It must be considered, however, that the concentration of lime in the tank was much greater than that expected to be used on natural beds, and that even if such a concentration were used, it would persist only a short time. It appears, therefore, that lime may be used without endangering the oyster population. Seed oysters survived in lime solutions as well as the adult oysters.

Claims that spreading lime over oyster bottoms will restore the normal color of green oysters were not substantiated by field or laboratory observations. Treatment with lime had no effect on the green color of the oysters.

Large numbers of hard clams, soft clams, and two species of mussels kept in tanks to which a large quantity of lime was added at monthly intervals survived this exposure for a period of 6 months. Mortality among these animals was not noticeably higher than in the control tanks. Field experiments also showed that there was no mortality which could be attributed to the effects of lime among mollusks dredged from the beds where experiments in the eradication of starfish were conducted.

Experiments performed at the State Hatchery at Noank, Conn., showed that the fry of flatfish will survive for 1 hour in a 1:1000 concentration of lime provided they do not come in contact with solid

particles. In the latter case death quickly results. Experiments with flatfish eggs obtained from the State Hatchery and taken to the Milford Laboratory showed that exposure in concentrations of 1.0 gr. of lime in 250 cc. of water did not materially increase the rate of mortality, but when the eggs were allowed to come in contact with particles of undissolved lime a mortality of almost 100 percent ensued.

Observations on the effect of lime on lobster larvae of the first, second, and third stages were carried out at the Noank Hatchery in June. In the filtered 1:10 solution the larvae of all stages survived for 4 hours. Similar results were obtained when larvae were subjected to a concentration of 1 part saturated lime solution to 2 parts of sea water. However, in a solution of 1 part of lime water to 1 part of sea water, a mortality of about 25 percent resulted at the end of 4 hours. All three larval stages appeared to be affected equally. In a saturated solution of lime all the animals died in 3 hours or less. In this solution the larvae of the first or earliest stage appeared to be the most resistant. Direct contact of lobster larvae with particles of lime resulted in death.

These experiments indicate that the use of quicklime on oyster bottoms should be restricted to seasons when no larvae of commercial species are present in the water, thus avoiding the danger of destroying them.

Distribution of starfish in Connecticut waters.—In cooperation with the Connecticut Shellfisheries Commission two surveys were made to determine the abundance of starfish on oyster bottoms between New Haven Harbor and Penfield Reef. The results of these surveys were immediately communicated to the oystermen, permitting more efficient eradication of this pest by private planters. It is planned to expand this service in the future by making surveys every 3 months and issuing the results in bulletin form to be distributed among the interested parties.

Improvements at the Milford station.—During the past fiscal year the Bureau obtained title to property at Milford, pursuant to the provisions of an act of the General Assembly of Connecticut, for the erection of a laboratory building and the establishment of grounds for experimental work on oyster culture. A special allotment of $35,000 was made by the Public Works Administration for the construction of a two-story brick laboratory. Work will begin early in 1939. Additional funds granted by the Works Progress Administration and Public Works Administration are being used for the construction of a sea wall and pier, filling the grounds, construction of tidal tanks, and other improvements.

Oyster propagation in North Carolina.—In the South Atlantic region there is great need of the development of oyster cultivation, and of special methods whereby oysters of good marketable size and quality can be grown on the extensive tidal flats. Although generally favorable conditions for oyster growth are found in these areas, the product obtained there is of inferior size and quality because of the overcrowding that results from prolific natural reproduction. One of the chief problems is the development of a practical procedure whereby seed oysters placed on the tidal flats can be protected from crowding and "fouling" of the shells by attachment of oyster spat, barnacles, etc., and grown to marketable size as single individuals of good quality. The three principal lines of investigation conducted

by Dr. H. F. Prytherch during the past year at Beaufort, N. C., in the study of this problem, were to determine (1) the rate and character of growth of seed oysters fastened to panels of cement, wood, and wire placed at different tidal levels, (2) the practicability of using devices of this type for intensive oyster culture, and (3) the possibility of utilizing specially constructed salt marsh ponds for concentrated growing of oysters by controlling setting, and preventing injury to the shells by the boring sponge.

One hundred and eighty seed oysters were attached to cement panels and studied individually with respect to growth in weight, volume, length, and width in relation to their position above and below low-water level and their orientation on the panels. The seed used were 1 year old, uniform in size and shape, and showed the following average measurements per oyster: Weight, 15.5 g.; volume, 95 cc.; length, 51 mm. (2¼ in.); and width, 30 mm. (1¼ in.). Three series of panels were placed at the main pier in Beaufort Harbor so that series No. 1 was 1 foot above mean low-water mark, series No. 2, 1 foot below this level, and series No. 3 on the bottom, or 6 feet below low-water mark. Each series consisted of 60 seed oysters that were cemented in groups of 10 on 6 panels and oriented in the following 6 different positions: Horizontal with left valve down, horizontal with left valve up, vertical with hinge up, vertical with hinge down, sideways with mouth up, and sideways with mouth down. Special care was taken to arrange the panels so that all the oysters in each series had the same environmental conditions.

The principal results of these experiments, briefly summarized, demonstrate that (1) the growth of oysters is most rapid in the tidal zone immediately above low-water level and slowest on the bottom, (2) the greatest increase in weight and size occurs in seed placed in a vertical position with the hinge uppermost, regardless of tidal level, (3) the next best growing position is sideways with the mouth of the oyster upwards, which produces the finest shape and depth of shell, and (4) the procedure of attaching seed to panels, screens, etc., and placing them in the most favorable tidal zone and individual positions, as indicated above, will yield an increase in volume of over 400 percent during the first year.

The remarkable growth obtained with the best group of oysters of the entire series showed the following increase during the first year: Weight, 360 percent; volume, 410 percent; length, 100 percent; and width, 94 percent. Every oyster of this group attained a good size and shape and exhibited unusual individual growth that ranged from an increase of 190 to 575 percent in weight, and from 210 percent to over 660 percent in volume. The results obtained thus far by the panel method of intensive oyster culture are encouraging as they indicate that a yield of over 5 bushels of marketable oysters, with a value of $5.00, may be obtained from 1 bushel of seed having an initial cost of 25 cents. This permits an expense of several dollars to cover the operations of placing each bushel of seed on panels and caring for them over a 2-year period. Studies are being continued to perfect an inexpensive type of panel that can be used indefinitely, and to improve the temporary coating that was applied to the shells of the oysters to protect them from attachment of spat, barnacles, boring sponge, etc.

Construction of a series of tidal ponds in the salt marshes has been completed with the aid of W. P. A. labor. Here principles of oyster culture similar to those described above are being tested on a small commercial scale. Several hundred bushels of seed oysters have been planted in the ponds and ditches, where, by control of water levels and tidal currents, it may be possible to produce oysters of good marketable size under protected conditions. This work may have important practical applications in demonstrating how the extensive salt marshes in the South Atlantic region may be converted into oyster-producing areas.

Oyster destruction by starfish in South Atlantic waters.—In the coastal waters of North and South Carolina destruction of oysters and other shellfish by starfish occurs to a limited extent in the more saline waters of sounds and bays adjacent to inlets. At the Beaufort Laboratory studies of the oyster-consuming ability of this pest were conducted over a period of 1 year by Dr. Prytherch. During the first 6 months (January–June) the 10 starfish in the experimental tanks devoured over 1,750 oysters ranging in age from 1 to 3 years. The number of oysters eaten per month over this period ranged from 183 to 456 and was greatest during March and least during June, when the starfish were undergoing the processes of gonad development and spawning.

After July first only large oysters, 3 and 4 years old, were kept with the starfish and during the following 6 months a total of 470 were eaten, the number per month increasing rapidly with the lowering of water temperature. The starfish were frequently observed to leave a partly consumed oyster and almost immediately begin an attack on another specimen, especially after they had been well fed for several weeks. Records of oysters attached to kymographs show that starfish are able to open large specimens in 3 or 4 hours. Analyses are being made of the secretions of starfish stomachs, as they are supposed to be an effective agent in opening shellfish.

Establishment of experimental farms in South Carolina.—Early in November the Bureau, in cooperation with the South Carolina State Board of Fisheries and the Works Progress Administration, initiated a program for rehabilitating and developing the oyster resources of the State through the establishment of a series of small experimental oyster farms. The primary purpose of this undertaking is to enable tide-water residents in the lower income brackets to obtain their subsistence, in whole or in part, by leasing and cultivating small plots of from 2 to 10 acres of oysters. The program differs from all previous experiments in presupposing that capital requirements will be at a minimum, and that primary materials, equipment, and supplies may be obtained or produced by the labor of the oyster farmer himself.

As early as 1890, interested persons were instrumental in having a survey of State oyster bottoms made by the Bureau of Fisheries, but only within the last few years have leasing laws permitted or encouraged extensive private holdings. A considerable acreage is now so held, but full development of the bottom cannot be accomplished until three major problems are solved.

The first requires development of an inexpensive method for obtaining single seed oysters in place of the massed clusters occuring naturally. This is essential to production of high quality oysters.

In the second place, variations in local water conditions must be understood so that advantage may be taken of those areas where growth and fattening occur most readily. On account of the long spawning season resulting from high water temperature, fattening occurs very late in the season. Southern growers are thus placed at a disadvantage in supplying fat oysters early in the season when the market is usually most favorable. Finally, methods must be devised for using suitable bottom below low-water mark. Under natural conditions, oyster spat attach themselves only between high and low water marks, with consequent restriction not only in the areas available for cultivation, but also in the number of hours the oyster may remain open for feeding.

In view of the importance of these and related problems to the Southern oyster industry, on November 1 the Bureau began an examination of available tidal streams in Beaufort County, S. C., with the view of selecting several areas suitable for small experimental oyster farms of several acres each. This work, in cooperation with the South Carolina State Board of Fisheries, was carried out by R. O. Smith, and several localities were marked for experimentation.

During 1939, various types of bottom will be tested to determine the most suitable treatment for seed and market oysters, and experiments will be carried out to find practical methods of seed collection on a small commercial scale.

Oyster investigations on the Gulf coast.—The oyster industry of the Gulf coast in general has for several years been in a relatively unsatisfactory condition, owing in part to the fact that it depends largely upon natural oyster beds which have been depleted by predators and by too intensive harvesting. The problems will apparently have to be solved by establishing oyster farms on privately leased or owned grounds and by studying the fundamental biological problems concerned before the industry of the coast can be conducted economically.

The program of oyster investigations which has been undertaken at the Pensacola (Fla.) Laboratory consists primarily of the following phases: (1) Establishment of an experimental oyster farm on a semicommercial scale to determine rates of growth and fattening, productivity annually per unit of bottom, and costs of production, including a study of natural hazards and predators of the Gulf coast. It is planned to compare the results with those of similar projects conducted by the Bureau in Atlantic waters. (2) Experimental laboratory and field studies of factors influencing the growth and fattening of oysters under conditions characteristic of most oyster-producing areas of the Gulf coast, particularly with reference to fluctuations in salinity.

Pending establishment of the experimental oyster farm, Dr. A. E. Hopkins has been working in close cooperation with the Florida Department of Conservation and the Works Progress Administration in a program of oyster planting and rehabilitation of exhausted natural beds in portions of Pensacola Bay. Observations to date indicate that East Pensacola Bay is very favorable for experimental study. Programs were also organized for the rehabilitation of natural oyster grounds in Apalachicola Bay, St. Andrews Bay, and Choctawhatchee Bay. In addition Dr. Hopkins made a number of trips to Mobile Bay at the request of the Alabama Oyster Com-

mission to advise on immediate problems and assist in forming a general policy of control of the natural beds.

During the year it has been demonstrated that the location of the Pensacola Laboratory, on Santa Rosa Sound, is most satisfactory for its purposes. The water was almost always clear and the salinity varied from about 20 to about 27 parts per thousand in ordinary weather to as low as 12 to 15 parts per thousand during 2 short periods of extreme spring freshets. The water temperature throughout the year followed closely that of the air, and averaged in midsummer about 74° F., in mid-winter about 60° F. Oysters, fish, and other organisms have thrived well in the laboratory aquarium.

With the assistance of relief funds from the Works Progress Administration and the Public Works Administration a program of development of the station was undertaken at the end of the summer. It is expected that early in 1939 the Pensacola station will be adapted to any type of fishery research.

Effect of pulp-mill pollution on oysters.—Investigations carried out by the Bureau between 1935 and 1937 at the Yorktown Laboratory have clearly indicated that pollution of the river by pulp-mill wastes has been responsible for the decline of oyster production. During 1938, Dr. Walter A. Chipman, Dr. H. N. Calderwood, R. O. Smith, and Lloyd R. Garriss have attacked the problem of determining what chemical or chemicals present in the pulp-mill effluents are the cause of the altered physiology of oysters. The investigators will later attempt to develop a means of eliminating such harmful substances.

The work has been continued on a cooperative basis with the Virginia Commission of Fisheries, which contributed $5,000, and with the cooperation of the College of William and Mary which granted the use of the chemical laboratory and office space in the college building at Williamsburg. In addition to the work in Virginia, special phases of the York River pollution problem were investigated in the Washington Laboratory by Dr. Galtsoff, with the assistance of Dorothy B. Hamilton. These were the abnormal shell structure and other pathological conditions found in oysters from the polluted areas of the York River.

In testing the effectiveness of pulp-mill wastes in reducing the amount of water pumped by oysters, it has been observed that only one of the various effluents entering the York River from the pulp and paper mill at West Point has a marked physiological action—that arising from the pulping process. This mill has three main sewer ditches; one draining a sludge deposit, one receiving wastes from the paper mill and causticizing section, and one carrying the wash waters from the diffuser and the digester building and evaporators.

Frequent sampling of the discharges from the sewers has revealed wide and irregular fluctuations in the character and physiological activity of the effluents. However, these effluents have been grouped under three main categories for the purpose of study; crude sulphate soap, foam from the mill sewer outlets, and weak black liquor.

At times considerable quantities of crude sulphate soap find their way into the effluents, being washed in from the ground surrounding the black liquor storage tanks. These soaps have a marked physi-

ological action in reducing the rate at which water is pumped by oysters. Fractionation of crude sulphate soaps has yielded portions both physiologically inactive and physiologically active. Studies are under way for the purpose of isolating, if possible, the single active constituent. A future study will be the determination of the part the physiologically inactive materials may play in the distribution and duration of the potency of the active portions.

Frequently large quantities of foam are observed in ditches leading to the river. Examination of the foam indicates the likelihood of its being a soap rather than a saponin. Further work is planned on the chemical nature and the effect on oysters of this material.

Tests of material entering one of the sewer ditches from an overflow of foam from the weak liquor storage tanks indicate that this material is chiefly a dilute form of the so-called "black liquor" which results from the digestion of the wood chips, with possibly an addition of a small amount of soap.

Chemical investigations are planned on black liquor samples for the purpose of finding whether any correlation exists between the alkalinity and volatile sulfide content of the various black liquor samples and the variations in effect on oysters exhibited by these samples. Fractionation of the black liquor will be undertaken, and efforts to develop a reliable method for the detection and determination in river waters of constitutents of the black liquor will be continued.

Tests on the physiological effectiveness of pulp-mill effluent have shown that storage of weak black liquor in air brings about a slow loss in potency. It seems that this change is chiefly in oxidation, since agitation in the presence of pure oxygen under pressure rendered the material physiologically inactive, whereas the effluent stored under hydrogen held its potency at a constant figure for periods of from 2 to 3 months.

SPECIAL SURVEYS

Under the direction of Dr. Galtsoff, a study of the sequence of fouling organisms on experimental panels exposed by the United States Navy at Cavite, P. I., and Guantanamo Bay, Cuba, was completed by G. Robert Lunz, Jr., and the report was prepared and submitted to the Navy Department. Preliminary experiments on the nature of the fouling film were carried out at Langley Field, Va.

At the request of the United States Engineers, Dr. Galtsoff made a survey of oyster bottoms in Onset Bay claimed to be affected by dredging operations in the Cape Cod Canal. Numerous samples of water and oysters were taken for examination. Certain areas were found to be covered with recent deposits of sand and mud and contained large numbers of dead oysters. Since the examinations were made long after the completion of dredging operations in this section, the cause of the mortality of oysters could not be ascertained.

Another survey of similar nature was made in Narragansett Bay at the request of the United States District Engineer in Providence. Fortunately, in this case, the survey was made while the dredging operations were still in progress. Samples of oysters were obtained from 16 stations on both sides of the canal. Examination of oysters

revealed no ill effect from the dredging operations. There was no accumulation of mud on oyster shells or in the shell cavities. The oysters appeared to be healthy and normal. It is planned to continue these surveys in Narragansett Bay as long as the dredging operations last.

Mortality of shellfish, Myrtle Sound, N. C.—At the request of the North Carolina Department of Conservation and Development, Dr. Prytherch made a survey of an unusual mortality of clams and oysters in the waters of Myrtle and Masonboro Sounds. It was found that hydrographical and biological conditions in these sounds had changed considerably since the construction of the Intracoastal Waterway and had proved to be detrimental to the growth and propagation of shellfish in this coastal region. The most important modification is the connection of the Cape Fear River with the southwest end of Myrtle Sound by means of a canal, approximately 100 yards wide, known as Snows Cut. This canal, being open at all times, permits a considerable quantity of fresh water, or water of low salinity, to flow into Myrtle and Masonboro Sounds. During flood stages of the river especially large quantities of fresh water, heavily laden with mud, pass continuously through these sounds for extended periods and enter the ocean at Masonboro Inlet. During the early part of August the unusual floods occurring in the Cape Fear River Basin produced such extreme freshening of the water in these sounds as to cause destruction of the natural supply of clams and oysters.

The value of the oyster crop of this region, which prior to 1932 was approximately $3,000 annually, decreased to less than $400 in 1936 and 1937. It is evident that the clam and oyster resources of this section, which have a combined value of $15,000 annually and serve as a means of food and livelihood for a large number of local people, should be restored after some satisfactory flood control devices have been installed to control the flow of fresh water from the Cape Fear River.

AQUICULTURAL INVESTIGATIONS

DR. H. S. DAVIS, *in charge*

It has long been recognized that our inland waters constitute one of the great natural resources of the country which, like other resources, are now suffering serious depletion. Industrial and agricultural development have so changed the nature of many waters that they are no longer suited to fish, while the majority of those that are still capable of supporting game and food fishes are badly overfished. These conditions can best be corrected by wise management combined with artificial propagation.

The work of the aquicultural investigations has developed along three principal lines. One deals primarily with field problems and the provision of much-needed information on the best means of obtaining the maximum production of game and food fishes consistent with environmental conditions. A second line of investigation is concerned with problems relating to the artificial propagation and rearing of fish, while the third deals with fish parasites and diseases, and their control.

TROUT

It is the purpose of the investigations on trout waters to obtain definite information on the annual drain to which the trout population is subjected by anglers, and the value of artificial stocking in maintaining a stable fish population. Attention is also being given to the correlation between normal production and the available food supply and other factors which must be given consideration in developing management policies.

Test streams.—The scientific work at the Pittsford (Vt.) station, under the direction of R. F. Lord, was again chiefly concerned with studies on test waters. Waters set aside for this purpose include three streams and one lake operated in cooperation with the State Fish and Game Service. On one of these streams, Furnace Brook, a State game warden was stationed each week end to examine anglers' catches for marked fish and to obtain data on the lengths and weights of all trout taken from the stream.

On both Furnace Brook and the South Branch of Middlebury River the total catch for the season was considerably less than in previous years. Unfavorable conditions during the winter of 1937–38, when heavy winter rains raised the streams to flood stage with much damage from floating ice, are believed to have been the cause of the exceptionally poor stream fishing throughout the State.

The superiority of rainbow over brook trout in contending with adverse conditions is again brought out clearly in the results from Furnace Brook. As pointed out in previous reports, no rainbows have been planted in Furnace Brook for years, while the stream is heavily stocked each year with fingerling brook trout and, for several years past, with yearling brook trout as well. Nevertheless, the catch of brook trout has shown a gradual decrease each year while the decrease in the catch of rainbows has been comparatively slight, with the result that the proportion of rainbows rose from 34 percent in 1935 to 38 percent in 1937. In 1938 this trend was accelerated; rainbows increased to 62 percent, while brook trout provided only 38 percent of the catch. Furthermore, the average catch of rainbow trout per angler, which had remained constant during the preceding years at 2.4, in 1938 jumped to 3.7.

The returns from 5,200 yearling brook trout planted in Furnace Brook in the fall of 1937 were very disappointing, only one percent of these fish being reported by anglers. The 1937 record of only 12 percent recovery was thought low but it remained for adverse wintering conditions to show how a fall plant of yearlings could be a total loss.

Fish population studies were made on the three test streams in cooperation with the United States Forest Service. The procedure was to block off a section of the stream with seines at the upper and lower ends. These were weighted with stones so as to prevent any fish entering or leaving the section. A dam of burlap sacks filled with sand was then constructed across the upper end of the section so as to divert the water into another channel. Any pools that could not be drained were pumped dry so that every fish present could be captured. The average number of trout per acre in three sections of Furnace Brook was 835, with a total weight of 35 pounds, 11

ounces. Only 15 percent of the trout were of legal size, 10 percent of these being brook trout.

In the South Branch of the Middlebury River the average number of fish (based on two sections) was 1,650 brook trout per acre, with a total weight of 54 pounds, 10 ounces. As in Furnace Brook, 15 percent of these fish were of legal size. There were no rainbow in Middlebury River and fish other than trout were too few to be of any significance.

The West Branch of the White River was found to have a much smaller population of trout. Three sections of this stream yielded an average of 376 trout, weighing 14 pounds, 10 ounces, per acre. This stream also supports considerable numbers of sculpin, dace, and suckers which, when added to the trout, give a total of 20 pounds, 14 ounces of fish per acre.

Studies on St. Marys River.—Monthly collections of bottom and chemical samples on the St. Marys River, Virginia, were continued during the spring, summer, and fall of 1938, to determine the effect of different current velocities on abundance of bottom animals in riffle areas. Samples collected during the past 2 years have been very uniform, with an average weight of slightly over one gram per square foot. In contrast with streams in the Southern Appalachians, there were fewer organisms in summer than at other seasons.

It is evident that stocking St. Marys River with fingerling trout has not produced worthwhile results and that rainbow trout disappear before they reach legal size.

Investigations in Pisgah National Forest.—The experimental fish-management program in Pisgah National Forest, North Carolina, was conducted for the second year in cooperation with the United States Forest Service. The project sustained an irreparable loss on January 4, 1939, in the death of Wm. M. Keil, who had been in charge of the project for the Forest Service since its inception. The work will be continued by Thomas K. Chamberlain, who has been conducting the biological studies for the past 2 years.

During the late summer and early fall of 1937 the streams of the Wildlife Management areas of the forests were stocked for the first time under the new program. After determining the carrying capacity of these streams, brook, brown, and rainbow trout were planted by the most approved methods. In order to develop and maintain satisfactory fishing it had been decided to plant larger fish and to develop some system of rotating the open season on the several watersheds in order that each stream might have a period of rest after being fished and restocked. Several of the streams were opened to a limited amount of fishing during the summer of 1938.

The danger of overstocking when streams are not rich in food has been demonstrated in several small streams of this area. In one instance a planting of brook trout averaging over 6 inches long was made in the fall. These fish remained in excellent condition through the winter but in early spring they began to decline, and, in late summer, 10 months after planting, their average weight was less than when first put into the stream.

Stream studies were carried out by Mr. Chamberlain to determine the rate of stocking for the various waters. Quantitative collections of food organisms were made from 977 square feet of trout-stream bottom in the Pisgah Forest alone. Observations were also made on

the trout present and on stream conditions in general. While streams in the Pisgah Forest received most attention, a start was made in studying the main streams of the Cherokee, Chattahoochee, and Nantahala National Forests, where food conditions appear to be much the same as in streams of the Pisgah Forest.

In general, the forest streams in this region may be classified as medium to poor. Most of them still suffer from excess of sediment, due largely to road construction and in some parts of the Pisgah Forest to overbrowsing by deer. However, conditions appear to be improving and were it not for uncertainties in future road construction the outlook would be distinctly encouraging.

Feeding experiments.—Extensive feeding experiments with fingerling, yearling, and adult trout were carried on at the Leetown station, supplemented by experiments with fingerlings at the Pittsford station. These experiments were designed primarily to determine the effect on growth, mortality, and egg production of dry meals fed at different levels and in different combinations.

In general, it was found that fresh meat is more efficiently converted into fish flesh than dry feeds but, owing to the lower cost of the latter, it is more economical to incorporate a considerable percentage of these products into the diet. Using a mixture of the better dry meals, best results were obtained when the meals were fed at a level of 40–50 percent.

One of the most striking results was the marked increase in growth following the addition of 3 percent cod-liver oil to a diet composed of sheep-liver and whitefish meal. Overfeeding failed to produce high mortality or any evident pathological effects.

Experiments with brood fish showed considerable variation in the hatchability of eggs from fish on different diets, amounting in some cases to over 50 percent. Overfed lots produced twice the number of eggs per female obtained from underfed fish on the same diet but the percentage of eyed eggs was more than 10 percent greater in the underfed lot.

Cooperative nutrition studies.—Studies on the nutrition of trout were continued under the cooperative agreement between the Bureau of Fisheries, the New York Conservation Department, and Cornell University. These investigations are carried out at the Laboratory of Animal Nutrition of the New York State College of Agriculture at Ithaca, N. Y., and at the Cortland (N. Y.) Hatchery of the Bureau of Fisheries. The staff conducting these studies consists of Dr. C. M. McCay, A. V. Tunison, A. M. Phillips, E. O. Rodgers, and C. R. Mitchell. Inasmuch as detailed reports of the progress of these investigations are published annually by the New York Conservation Department, only a summary of the results is included in this report.

The study of the growth rates of four species of trout during a period of more than 5 years (March 10, 1933–September 16, 1938) has been terminated. The trout used were lake, brown, rainbow, and brook. In this study the best survivors were the lake trout. These continued to grow, but at a very slow rate, until discarded. The brook trout were the poorest from the point of view of survival. The growth curves of these four species ran parallel throughout.

During the past few years many new vitamin concentrates have been made available, opening new possibilities for determining the needs of animals for vitamins. During the past year new studies

were made employing synthetic diets supplemented with liberal supplies of vitamin concentrates. All recognized vitamins were included in these supplements but this mixture could not replace the factor H of fresh meat. Present knowledge about the part any of the vitamins play in the growth and well-being of trout is extremely limited.

New attempts were made to prepare concentrates of factor H from liver but with little success. Ten percent of fresh liver added to a synthetic diet seems to satisfy the requirements of trout for all vitamins. In accordance with our earlier studies it seems that liver retains part of its factor H when dried in vacuo.

Studies with meats and fish preserved in various ways have been continued. Some success has resulted from feeding meat such as spleen preserved with salt. No injurious effects have resulted from feeding high levels of salt to brook trout.

Since ordinary dry feedstuffs contain about 10 percent of moisture, an attempt has been made to dehydrate fresh meat by mixing it with very dry feed mixtures. By starting with a very dry diet sufficient fresh meat can be added to bring the mixture to its normal content of about 10 percent. Preliminary tests with this method indicate that part at least of the factor H is preserved.

Intermountain Region.—Fish management work in the Intermountain Region in cooperation with the United States Forest Service and the fish and game commissions of the several States, which had been discontinued for several years, was resumed with the appointment of Dr. Stillman Wright as regional biologist. Dr. Wright established his headquarters at Logan, Utah, on June 9, where the State Agricultural College has very generously provided adequate laboratory facilities for him and his assistants. Since entering upon his duties Dr. Wright has spent considerable time familiarizing himself with conditions in this region, in the course of which he has traveled approximately 17,400 miles by automobile.

Trout are the principal game fishes of this region in which, as elsewhere, the number of anglers and consequent intensity of fishing is increasing very rapidly. Failure of the fisheries to maintain themselves under the heavy demands of the public is evident in the streams, particularly those near centers of population. In lakes and reservoirs excessive removal of trout is usually followed by a great increase in the less-desirable species. Factors other than overfishing are, however, involved in the general decline of the fisheries in this region. Silting, resulting from overgrazing and accelerated erosion, makes streams less suitable for trout. In many streams hydroelectric and irrigation projects interfere with normal migrations, while fluctuations of the water level in reservoired lakes interferes with normal spawning and may have other detrimental effects. Because of the variety and critical nature of the many problems involved, it is evident that for some time investigations in this region must be directed toward the formulation of management plans for waters showing possibilities of immediate improvement of fisheries resources.

During the past summer special attention was given to Fish Lake, Utah, which formerly supported a highly productive fishery for rainbow, mackinaw, and brook trout. Some years ago the Utah club was introduced and has since become extremely abundant. As the

chub increased in numbers the brook trout decreased in abundance and average size until it is now a negligible item in the catch. There is reason to believe that the rainbow and mackinaw are also on the decline.

The results of earlier studies combined with those of last summer have made it possible to formulate a program of management which gives promise of improvement in the fishery. The following recommendations have been made to the State Department of Fish and Game: (1) That a program of eradication of the Utah chub be instituted, (2) that a forage fish especially suited to the needs of the mackinaw trout be introduced, (3) that plantings of rainbow and mackinaw trout be continued, (4) that the present catch limit be drastically reduced and that attempts be made to develop other lakes for fishing, so as to decrease the fishing intensity in Fish Lake.

In the search for a forage fish to meet the needs of the mackinaw trout, attention was directed to Bear Lake, Utah and Idaho, which has three species of Coregonidae found nowhere else. One of these, the Bonneville cisco (*Leucichthys gemmifer* Snyder), may prove to be a valuable forage fish, and a study of its life history has been begun. A more detailed study of Bear Lake is planned for 1939. At the present time the trout fishery in this lake is in a deplorable condition and a number of factors conspire against improvement.

California trout investigations.—The work of this research unit has remained under the direction of Dr. P. R. Needham, with headquarters at the Natural History Museum of Stanford University. Dr. Osgood R. Smith was appointed to the staff in the position of Assistant Aquatic Biologist. The cooperative agreement that had been in effect since 1932 with the California Division of Fish and Game was abrogated by mutual consent on July 1, 1938.

Cooperation with the United States Forest Service was continued, but lack of funds limited the extent of the work. Angling catch records were taken for a second season on Fish Lake, in the Umpqua National Forest, Oregon. Lack of funds caused abandonment in August of the survey of the North Fork of the Umpqua River and its tributaries when only partially completed. The survey of lakes in the Willamette National Forest was completed and a report covering the entire three years' work and containing stocking policies for all lakes suitable to fish life is now being prepared. A survey of lakes in the Columbia National Forest in Washington was begun, and it is planned to continue the work next season if funds are available.

Complete catch records were secured for a second season on Squaw Creek in the Shasta National Forest, Calif., and a report is being prepared that will cover the 2 seasons' activities.

Loss of Mexican trout.—The flood of March 2, 1938, in southern California completely destroyed the Forest Home State Fish Hatchery, near Redlands, and with it both the adults and eggs of *Salmo nelsoni* brought to California from Baja California, Mexico, in the spring of 1937. An attempt will be made to secure another lot of these fish for breeding purposes.

Convict Creek experimental stream.—Experiments to determine the survival rates of hatchery-reared trout planted under controlled conditions were continued. Fifteen plants of marked rainbow and

brown trout were made in the experimental stream, 13 of which were successful. The survival from plants of advanced fry and eyed eggs gave further confirmation of last year's results. From a plant of 3,000 eyed cutthroat eggs, 465 fish, or 15.5 percent, survived after 51 days. A slightly higher survival of 21.7 percent was obtained from a plant of 2,000 unfed fry. These results were obtained under light predation, and survivals are slightly higher than any obtained last year. In contrast, a plant of 1,000 unfed fry showed a survival of only 1.4 percent under heavy predation, 64 wild trout being taken from this section at the end of the experiment.

Brown trout fingerlings, planted at the usual size at which they are planted from State hatcheries, showed surprisingly high survivals after 3 months. For instance, in one section a survival of 76.4 percent was obtained after 94 days, in spite of the fact that 117 wild trout were also present in the section. These fish were planted at a length of 1.5 inches and averaged 3.2 inches at the end of the experiment. By way of comparison, wild brown trout of the same age, netted from Convict Creek, showed a survival of over 89 percent after 97 days under heavier predation.

Small rainbow trout, averaging 1.7 inches in length, planted in two experimental sections, showed survival rates of 75.6 and 83.1 percent, respectively, after 95 days. These fish were planted without removing wild fish and no effort was made to protect them from other predators.

One of the most surprising results has been the large numbers of naturally spawned fish that are found in the experimental sections at the end of the season. This year a total of 1,123 wild brown, rainbow, and eastern brook trout were removed from the 15 experimental sections, an average of 74 wild fish per section.

Some much-needed improvements were made during the past year, including the construction of a small cabin for living quarters, and a few changes in the experimental section. Floodwaters in late June interfered with the experiments to some extent. Late in the fall a flood diversion ditch was constructed which will make it possible to divert at least a portion of high water out of the main channel and around the experimental area.

Shasta Dam survey.—A party of four biologists, employed by the United States Reclamation Service, has been engaged in an investigation of the salmon-salvage problems resulting from the construction of the Shasta Dam on the Sacramento River. This work is under the immediate direction of Dr. Smith. During the summer most of the spawning areas above the dam were located and measured to determine the extent of such areas that will be destroyed upon completion of the dam. Streams below the dam were also examined for suitable spawning areas.

On the basis of counts made of salmon passing over the fish ladder at the irrigation dam at Redding, it is estimated that there are approximately 20,000 salmon in the fall run alone, which would indicate a potential deposition of over 70 million eggs in the area that will be cut off by the dam.

Dam debris survey.—Late in June a crew of four men was employed by the United States Engineer Corps to make a study, under the direction of Dr. Smith, of the fisheries problems arising from the

construction of three dams on the American and Yuba Rivers in California. Data were gathered during the summer by standard stream survey methods and, in addition, two men were employed to count salmon ascending the rivers. The counts were incomplete and do not include a reputedly sizeable steelhead trout run. They do, however, indicate that it will be mainly sport fishing and not the commercial salmon fishery that will be affected by the dams and mining debris.

Survey of Pyramid Lake, Nevada.—A survey of Pyramid Lake and its fisheries problems was made between March 7 and June 8 at the request of the Indian Service. Francis H. Sumner was stationed at the lake to gather biological, physical, chemical, and historical data on the lake and on Truckee River, which formerly was the spawning ground of great runs of cutthroat trout. With the aid of Indian wardens a record was kept of the commercial catch made by the Indians, which has declined greatly in recent years. Length-frequency and age studies show that the run is at present made up almost entirely of old fish, averaging 34 to 35 inches long, and that the younger age groups are not represented. This age and frequency is the reverse of that usually found in an over-exploited fishery. It appears that the run was but a remnant of a race that has practically ceased to reproduce, from lack of spawning facilities. Overfishing by the Indians has probably been a factor in depleting the run, but it is evident that the diversion of the Truckee River water has been the major cause. It is considered doubtful that rehabilitation could be effected by any means.

BASS

Studies on streams in Virginia and West Virginia.—Field work on bass streams, begun in 1936, was continued at the Leetown (W. Va.) station by E. W. Surber and George E. Klak.

These studies are designed primarily to determine the extent and efficiency of natural propagation of bass and the effect of intensive fishing on the bass population. They show that, even in heavily fished waters, there is little danger of the bass population being seriously depleted if adequate spawning facilities are available. Intensive fishing frequently results in excessive numbers of small bass, with consequent reduction in the abundance of forage fishes. It is apparent that the remedy is to build up the food supply and that stocking with young will only tend to intensify the unbalanced condition.

Monthly series of bottom samples were collected from the experimental sections of four streams, namely, the Cacapon River, South Branch of the Potomac River, North Fork of the Shenandoah River, and the Shenandoah River. This series of samples duplicates those taken in previous years. Special attention was given to measurements of current velocities at all sampling stations. Laboratory work on the bottom samples has been completed, but the data have not yet been analyzed.

Studies of the extent of natural propagation were continued in these four rivers. In contrast with previous years, interruption of the spawning season by cold weather and muddy waters brought about a second spawning early in June. In previous seasons spawning was completed by the 1st of June. The number of bass nests

per mile was 70.7 in the Cacapon River, 81 in the South Branch of the Potomac, 24 in the North Fork of the Shenandoah, and 11 in the Shenandoah River proper. It is believed that in ordinary years an excessive number of fry are produced in the first two rivers. During the past year, however, high and muddy waters destroyed the fry as they rose from the nests and there was a decided scarcity of fingerling bass throughout the season. Routine monthly collections of fishes showed that a reduction in the numbers of fingerling bass is accompanied by an increase in the forage fish population. After July, collections of bass fingerlings for study became increasingly difficult or impossible because of their scarcity.

As in previous years, conditions in each stream were found to differ in many respects and each would require different treatment to bring about improvement in fishing. Minnow surveys were made in 11 experimental sections in an attempt to determine whether reasonably reliable data could be collected on the size of the forage fish populations in the four rivers concerned.

Investigations in Florida waters.—In recognition of the need for extensive studies on black bass and other fresh-water game fish in Southern waters, and their propagation by artificial means, headquarters for this work was established at the hatchery recently acquired by the Bureau at Welaka, Fla. This station, located on the banks of the St. Johns River, is admirably adapted to experimental work. There are a large number of ponds, ranging from seven-eighths to 2 acres in area, which have recently been remodeled to make them more suitable for experimental work. New buildings have been constructed which will provide adequate laboratory, office, and living facilities for biologists working at the station. Opposite the station, on the west side of the St. Johns River, is the Ocala National Forest, which contains several streams and a large number of lakes rich in aquatic life. Through a cooperative agreement with the United States Forest Service and the Florida State Commission of Game and Freshwater Fish, eventual management and control of all lakes in this area is contemplated.

Investigations in this area, both at the Welaka station and in the field, are being conducted under the direction of O. Lloyd Meehean. Mr. Meehean began his work on the waters of the Ocala Forest in April 1938, and later moved his headquarters to Welaka.

A survey of the principal lakes in the Ocala Forest was carried on during the summer of 1938 to provide information to be used in developing a management program for these lakes. The survey included plane-table mapping of the lakes by a crew of C. C. C. enrollees, complete soundings of each lake, and the determination of the species of fish present and their relative abundance. From this survey maps have been prepared showing bottom contours, the location, kind, and extent of weed beds, and other pertinent information.

Based on this survey, a stocking program has been worked out for 19 lakes that are fully controlled by the Forest Service. Most of the lakes are to be stocked with bass and sunfish, but several which appear ideally suited to crappie have been reserved for this species.

To determine the fishing demand to be expected on lakes of the forest, checking stations were set up on two of those most accessible

to anglers. At these stations a complete census was started on May 21, the opening day of the fishing season, and will continue until the close of the season on March 21, 1939. Bottom samples, two types of plankton samples, and chemical data are also being collected on these lakes.

In addition to the lakes under management, seven ponds have been set aside for experimental work. This number will be increased as needed. These ponds will be utilized for stocking experiments and study of methods to increase the food supply of game fish in these waters, as the basis for improvement in the management program.

In the Choctawhatchee National Forest there are a number of streams that are inhabited by largemouth bass at the lower end where they enter coastal bays, but which contain no game fish higher up. These streams are peculiar in that the temperature of the water is about the same throughout the year. A study is being made of the physical conditions and life in these streams to determine how they can best be utilized.

Experiments relating to hatchery problems will be started early in 1939 when the remodeled ponds at the Welaka station will be ready for use.

PARASITES AND DISEASES OF FISH

Facilities at Seattle, Wash., for the study of problems relating to fish diseases were greatly increased during the past year. These studies are under the direction of Dr. F. F. Fish. Two experimental laboratories are now available, each operated for a slightly different purpose. One is an enlargement of the field laboratory constructed at the Quilcene (Wash.) hatchery in 1937. The original temporary structure has been replaced by a permanent building constructed by the Division of Fish Culture according to plans provided by Dr. Fish. As this laboratory was planned primarily for testing scientific discoveries under controlled field conditions, it is not suited to all types of experimental work.

A second experimental hatchery has been provided, through the generous cooperation of the University of Washington, in the basement of one of the university buildings. This laboratory is supplied with chlorinated water, which is subsequently dechlorinated by passage through an activated carbon filter, thus assuring a disease-free source of water. The laboratory contains 24 small troughs which have proved highly satisfactory for this type of research. The main water supply to the troughs is controlled by a manually operated master valve and mixing chamber which permits the maintenance of any desired temperature in the troughs. When finances permit, the water supply of 10 of the experimental troughs will be additionally controlled by automatic thermostatic valves.

Much of the long-term scientific program of the Seattle Laboratory had to be considerably modified during 1938 because of the lack of suitable facilities during the construction period. As long as the original Quilcene Laboratory could be used, a series of toxicity studies was maintained to determine the maximum nontoxic concentration of disinfectants which fish could withstand for various

lengths of time. The value of these concentrations in preventing certain diseases was then tested at producing hatcheries by means of routine 1-hour applications at weekly intervals.

During the course of the experiments, which extended over a period of 3 months, a serious outbreak of the Western type of gill disease occurred at the Birdsview (Wash.) Hatchery, and a mild outbreak at the Quinault hatchery. Prolonged treatments with malachite green, potassium permanganate, and chlorazene failed to exert any beneficial effect in preventing the disease. A considerable drop in the mortality followed treatments with copper sulphate and boric acid, but further experiments with both chemicals will be necessary before any conclusions concerning the prophylactic or therapeutic values of these disinfectants are justified.

During 1938 a new technique was developed for treating fish in relatively large volumes of water, such as are found in circular pools and in raceways. In this method the water supply to the pond is shut off and the amount of predissolved disinfectant necessary to attain the desired concentration is added. The water is kept mixed and aerated during the treatment by means of a centrifugal pump.

After completion of the new laboratory at Quilcene, a series of controlled infection experiments with the protozoan parasite *Cyclochaeta* were initiated. The purpose of the experiments was not only to trace the development of the disease under controlled conditions but primarily to determine the relationship between daily losses and the actual degree of infection present. The results indicate that while daily losses are by no means an accurate index of the degree of parasitism, and are unsuitable for experimental purposes, they are sufficiently accurate to serve all practical purposes.

Pathological studies on *Henneguya salminicola*, a myxosporidian parasite in the body musculature of several species of Pacific salmon, and similar studies on *Myxobolus inornatus* n. sp., a myxosporidian found in the body musculature of the black bass, were completed and the results prepared for publication.

At the Leetown station E. W. Surber completed a study of a peritrichous ciliate of the genus *Scyphidia*, which occurred in large numbers on the gills and bodies of black bass at this station. This parasite was discovered on a lot of largemouth fingerlings which suddenly stopped feeding. No attempt was made to control the infection and within a few days the fish suffered a sudden and almost complete mortality. Although a few *Dactylogyrus* and *Cyclochaeta* were also found on the fish the *Scyphidia* are believed to be the principal cause of the mortality. This is borne out by the fact that the same pond contained numbers of golden shiners which were more heavily infected with *Dactylogyrus* than the bass, yet suffered only a slight mortality. No *Scyphidia*, however, could be found upon these fish.

Dr. Davis continued his studies on a suctorian parasite of the smallmouth black bass which has been the cause of considerable mortality at Leetown among bass of all ages. This parasite is evidently widely distributed, since it has been found at several hatcheries in New York, New Jersey, and Maryland.

The "Disease Service" continued to function during the past year, about the same number of specimens being received for diagnosis as

in previous years. One very gratifying feature is that some of the hatcheries have ceased to be steady clients of the service, which would indicate that the common diseases are now under better control.

Dr. Davis spent some time at the York Pond (N. H.) station in connection with an outbreak of furunculosis. In an effort to eradicate the disease the trout were either removed or destroyed and the ponds and hatchery disinfected with chlorine and hydrated lime. Owing to the nature and extent of the ponds this was a very difficult task but it is believed that it was accomplished successfully.

INVESTIGATIONS IN INTERIOR WATERS

Dr. M. M. Ellis, *in charge*

POLLUTION STUDIES

Headquarters for the pollution studies have continued at Columbia, Mo., where the University of Missouri has courteously provided laboratory space and facilities. A subsidiary laboratory at Fort Worth, Tex., has also been maintained. The various phases of the pollution investigations are so organized that they contribute to the central purpose of determining the suitability of particular waters both in the stream and in the hatchery for different types of fishes, the detrimental action of many substances which enter streams or water supplies either naturally or through pollution, and reliable means for measuring the condition of the fish themselves. In this work cumulative effects and impairment of vital functions are receiving more attention than the immediate lethality, as the former are both more insidious and far reaching than the latter.

Three major lines of investigation are in progress at the Columbia field unit and the Fort Worth Laboratory.

Analytical studies.—Waters, muds, and aquatic organisms collected in the field are sent to the central laboratory for detailed analysis. Determination of these samples is carried out by Dr. B. A. Westfall and assistants. In addition to the materials collected in the course of field work conducted by the staff, a large number of samples are sent in for analysis by the various State agencies.

Bioassays.—The specific effects of materials found in waters, muds, and pollutants, on living fish and other aquatic animals, are determined by the bioassay method. The bioassays of pollutants sent to the Columbia unit by State authorities and other sources have grown to be an important activity of the laboratory, with 50 to 200 such assays constantly in progress. Equipment and procedures have been so standardized that it is possible to assign a considerable portion of this work to analytical assistants who carry on these tests as routine tasks.

Physiological investigations.—The underlying causes for the actions of the various substances found in natural waters and pollutants on living fish are sought through studies of the physiology of fish. This phase of the work is under the direct supervision of Dr. Ellis and is conducted both in the Columbia Laboratories and at Fort Worth. A major field of physiological investigation during the year was a study of the effects of various components of larvacides and herbicides on fresh-water fishes and associated aquatic food

organisms. As the biochemical and physiological tests are quite exacting, each fish is maintained and studied as a separate patient, frequently for a period of several months. More than 200 such fish are under observation at Columbia, and upwards of 500 catfish are being studied as part of this investigation at Fort Worth. These studies have progressed to the point where it is possible to conclude that there is impairment of the growth and nutrition of fishes in waters treated with even small quantities of arsenicals and several other materials commonly used as mosquito larvacides. A separate report on this subject will be prepared early in 1939.

During the latter part of the year physiological studies were begun to determine the effects of several substances dangerous to fish life which were found in natural waters in the West in the course of the summer's field investigations. These studies are being carried out in both the Columbia and Fort Worth Laboratories.

Summer field surveys.—During the summer of 1938 intensive studies of stream pollution were made throughout the greater part of Western United States, and many new data were collected on the nature and effects of polluted waters. Observations were made in the States of Texas, Arizona, Nevada, California, New Mexico, Oregon, Washington, Idaho, Wyoming, Montana, Minnesota, North Dakota, and Nebraska. About 5,000 analyses were made in the field and additional material was returned to the laboratory at Columbia, Mo., for further analysis.

After leaving Columbia early in the summer, Dr. Ellis and field party proceeded to the Fort Worth (Tex.) Laboratory where particular attention was given to the catfish investigations in progress there. From Fort Worth the party proceeded to Uvalde, Tex., where a study of water conditions indicated the source of at least one of the difficulties hampering pond operations, not only at Uvalde but also throughout the Southwest. While in Texas, the party had an opportunity to make direct observations on the silt and salt loads of floodwaters, obtaining valuable data.

Studies of impounded waters continued at Elephant Butte Reservoir in cooperation with the United States Reclamation Service and the National Research Council, and at Lake Mead in cooperation with the same agencies and the National Park Service. At Elephant Butte opportunity was afforded to use a new piece of apparatus recently developed in the Columbia Laboratories by means of which direct determinations of silt, turbidity, water temperature, and light transmission were possible inch by inch throughout the entire depth of the lake. This new apparatus gave valuable detailed data confirming previous observations made by less accurate methods. Application of various new methods and pieces of apparatus to surveys of these western impounded waters is proving very profitable and is providing a wealth of new information on water problems which has not been available previously. A manuscript on Lake Mead is planned, comparable to the one on Elephant Butte now nearing completion.

After completing the work at Lake Mead the party proceeded to the geyser fields and the Hot Creek region in California where a large series of observations were made. At Gold Beach, Oreg., work carried on during the previous summer on the Rogue River mining problems was checked and extended.

In the Mount Rainier section studies of glacier waters were continued. In addition to making observations on the three major glacier fields, Nisqually, Puyallup, and Edmonds Glaciers, the party studied a large number of streams receiving glacier waters. After completing the work in the vicinity of Mount Rainier the field party moved over into the Columbia drainage and made extensive observations on the Columbia River and its tributaries above and below Rock Island Dam. These data form parts of series collected in previous years which it is believed will ultimately be of service in answering some of the questions concerning the establishment of new salmon runs in these streams.

Dr. Westfall, who carried on laboratory experiments at Columbia during the months of June and July, and looked after the field material as sent in, joined Dr. Ellis' party at Lake Mead the second week in August. Enroute to Lake Mead Dr. Westfall, with field truck and equipment, covered various streams in northern New Mexico and Arizona. Dr. Westfall remained with the main party from Lake Mead to Glacier Park, then proceeded east through Montana and North Dakota to check water conditions in the Fort Peck Dam area, the headwaters of the Missouri, and at Jamestown and Valley City, N. Dak., where proposed hatcheries are being considered. From North Dakota he proceeded east through Minnesota and made an investigation of the pollution situation on the Rainy River.

The main field party proceeded south from Glacier Park through the lead district of north Idaho and the copper district of Montana to check observations at regular stations, thence through Yellowstone Park and Wyoming, giving particular attention to streams from geyser fields or from heavily mineralized districts. Reaching the southern Wyoming line, the party was again split so that two sets of streams, one across Colorado and one across Nebraska, were sampled by the returning parties enroute to the Columbia (Mo.) station.

Because of improved apparatus and new methods used, summer field studies were much more detailed during 1938 than heretofore. Special apparatus was carried, by means of which physiological studies of the fish were made in the field. This innovation proved very successful and yielded not only valuable but also surprising data in many cases. It is well known that moving fish or other animals from their natural habitat, even under the most rigid precautions, frequently results in physiological changes so that the examination of these live animals in the laboratory often fails to give a true picture of their conditions in the field. With the special physiological and biochemical apparatus carried the physiological observations and tests were made immediately at the stream in which the fish were living. It is believed that these data will supply a much truer picture of the physiology of our fresh water fishes than has hitherto been available.

Summary of progress during 1938.—Studies of stream pollution during the past year have demonstrated more clearly than ever before the fact that high dilutions of many substances, introduced by man into streams, lakes, and reservoirs, or entering these waters from natural sources, have cumulative actions and seriously impair the vital activities of food and game fishes. By continued action these substances, even though they be present in the water in very small

quantities, are often more insidious and far reaching in their effects on fish life than other more obvious pollutants which kill fish at once. Collectively, therefore, the pollution investigations determine the suitability of particular waters, both in the stream and in the hatchery, for various types of fishes, the detrimental actions of specific substances, and reliable means for measuring the condition of the fish themselves.

This year's work has shown, among other things, that very small quantities of arsenicals and several other materials introduced into or placed on waters as mosquito larvacides, impair the growth and nutrition of fishes in these waters in addition to building up serious hazards of lethal poisoning; that certain combinations of some of the less common minerals which are found in small quantities in various western streams are responsible for internal injuries to trout and other fishes in these waters, and that these internal conditions are correlated with decline in weight and finally with the death of the fish in such streams; and that small quantities of several inorganic salts quite widespread in southern and western waters are the cause of low productivity and on occasion of the sudden death of large numbers of fishes in fish hatcheries, streams, and reservoirs receiving such waters.

Because of these findings, and other similar studies in progress, the listing of streams throughout the United States which can be designated as unsuitable for fish plantings, or in which low productivity may be expected because of these biochemical factors, is in progress.

As impounded waters are particularly subject to concentration of the various minerals and other compounds which constitute natural hazards to fish and other aquatic life, the detailed chemical and biological studies which have been in progress for some time at Elephant Butte Reservoir, N. M., and Lake Mead, Nev., have been continued throughout the past year.

Acute pollution problems continue to claim considerable attention, and specific cases of paper-mill pollution have been studied in Florida, South Carolina, North Carolina, and Minnesota; of phosphate-mine pollution in Florida; of copper, lead, and zinc mining operations in Idaho, and Montana; of combined industrial pollution in New York and Mississippi; and of placer gold mining in Oregon. Reports on these investigations have been submitted or are now in preparation. This unit has continued to advise both public and private agencies on matters of pollution and water conditions, and many State officials, various industrial concerns, and numerous private individuals have been given specific answers to particular problems throughout the year.

ICHTHYOLOGICAL INVESTIGATIONS

Fishes of the Canal Zone and Panama.—The study of specimens and data collected in 1935 and 1937 was continued by Dr. Samuel F. Hildebrand. The study of the fresh-water material was completed, and the results have been embodied in a publication entitled "A New Catalogue of the Fresh-Water Fishes of Panama." In this catalogue 127 species are listed, including 9 new ones. The origin and distri-

bution of the fishes of the Isthmus of Panama are discussed, and considerable life-history data are given. A section is devoted to the successes and failures of introduced fishes, setting forth precautions that should be taken and outlining a plan for future introductions.

The study of specimens and data collected in the locks of the Panama Canal, as well as elsewhere in the Canal, was completed. A full report was prepared, listing the animals taken and containing special information on the use of the Canal, especially its locks, as passageways for fishes.

American anchovies.—The taxonomic revisional studies of the American anchovies by Dr. Hildebrand were continued, especially in connection with the work set forth in the preceding paragraph. The study of the Atlantic forms has been carried about as far as the material available will permit, but only a few of the Pacific coast species have been studied.

Fishes of Tortugas, Fla.—The editorial work and study of specimens necessary in completing and getting ready for publication an unfinished monograph on the fishes of Tortugas, Fla., left by the late Prof. William H. Longley, has been far advanced during the year by Dr. Hildebrand. The points of chief interest in this work are the underwater observations and photographs of the shallow-water fishes, and the numerous additions of West Indian fishes to the American fauna.

General systematic studies.—Revisional studies of the systematics of American fishes were continued by Isaac Ginsburg, with special reference to the Gobiidae. New species were described, based chiefly on material studied from the gobies obtained by Dr. Hildebrand in Panama; material submitted for study by the Bingham Oceanographic Foundation; and material from the Hancock Collection, Stanford University, and from the National Museum.

INDEPENDENT ACTIVITIES OF THE FISHERIES BIOLOGICAL LABORATORIES

WOODS HOLE, MASS.

Owing to the lack of a special appropriation, the Woods Hole station was opened last summer to only a limited number of investigators. In addition to Dr. Galtsoff, Acting Director, and his staff, who were engaged in shellfisheries studies, the following persons occupied laboratory space: Dr. H. M. Smith, Associate Curator in Zoology, United States National Museum, working on otoliths of local fishes and a report on fresh-water fishes of Siam; Dr. Edwin Linton, University of Pennsylvania, helminth parasites of fishes; Dr. Raymond W. Root, College of the City of New York; and Dr. Clark Black, of Swarthmore College, the effect of carbon dioxide upon the oxygen-combining power of marine fish blood; Dr. d'Alte A. Welch, Johns Hopkins University, the variations and distribution of Hawaiian tree snails; Milton J. Lobell, United States Bureau of Fisheries, age composition of the winter flounder population and general studies of the life history; Julian G. Griggs, George Washington University, fertility in the oyster under various conditions.

In September the laboratory sustained considerable damages from wind and a tidal wave which swept the grounds, flooding the basement of the hatchery and the residence and destroying the seawall and pier. No serious damage was done to the floating equipment or to the scientific apparatus.

BEAUFORT, N. C.

Research facilities for the study of marine fishery problems in the South Atlantic region were provided throughout the year at the Beaufort Laboratory. The chief investigations conducted here by the Bureau's staff, under the direction of Dr. H. F. Prytherch, consisted of experiments and studies with reference to oyster culture; destruction of oysters by starfish; the propagation of diamond-back terrapin; the utilization of salt-marsh pools for propagation of fish and shellfish; and mortality of shellfish in Myrtle Sound, N. C.

Assistance and advice was given to the following agencies, as indicated, on matters pertaining to the marine fisheries and fishery industries of the South Atlantic region; United States Engineer Department, construction of new inlets in the vicinity of Cape Lookout for improvement of the fisheries of Core Sound, N. C.; North Carolina Department of Conservation and Development, continuation of oyster-planting programs and investigation of oyster mortality in Myrtle Sound; Duke University, construction of five building units and pier of biological laboratory on property adjacent to the Beaufort stations; Union Carbide and Carbon Corp., continuation of corrosion tests with stainless steel cable under marine conditions; Aluminum Company of America and the United States Navy, antifouling and corrosion tests on aluminum panels; Fordham University, Chemistry Department, tests of the antifouling value of special paints for marine use.

Laboratory facilities for biological research have been provided for 27 independent investigators from other institutions who were engaged in the following studies: Dr. H. V. Wilson, professor in the University of North Carolina, cellular reactions to drugs; Dr. A. S. Pearse, Duke University, assisted by James W. Littler and Henry A. Walker, polyclad worms and crustacean parasites; Dr. Frederick F. Ferguson, University of Virginia, the marine turbellaria; Dr. M. A. Stirwalt, University of Virginia, assisted by Frances C. Smith, morphology of marine rhabdocœles; Dr. George H. Girty, United States Geological Survey, the ecology of living mollusks; Dr. W. C. George, University of North Carolina, comparative hematology; Dr. Bert Cunningham, Duke University, effects of temperature on the rate of development of turtle eggs; Dr. Katherine R. Jeffers, Duke University, the effect of pituitary hormones on the ovaries of marine fishes; Dr. Arthur E. Woodhead, University of Illinois, trematode parasites of fish, especially larval forms in oysters; Dr. F. J. Brinley, North Dakota State College, physiological studies of fish embryos; Dr. William L. Engels, University of North Carolina, terrestrial vertebrate fauna of the coastal banks; A. B. Hardcastle and Margaret S. Hardcastle, a protozoan parasite of the menhaden; Sidney Shapiro, Columbia University, differential growth in the Scombroidei; Coit Coker, University of North Carolina, embryology of echinoderms; Roscoe E. Hill, University of Illinois, ecological studies of marine fauna; Nelson G. Hairston, University of North Carolina,

development and reproduction in hydroids; Russell A. Huggins and Sara E. Huggins, Western Reserve University, the scale size of fish in relation to body size; Gordon H. Tucker, University of North Carolina, gonad development in ascidians; J. Albert Fincher, University of North Carolina, spermatogenesis in sponges; Stephen W. Gray, University of Illinois, physiology of the invertebrate heart; H. J. Lewis and Hervey Lewis, Narragansett Bay Oyster Co., spawning and larval development of oysters.

Propagation of the diamond-back terrapin.—A record hatch of 13,600 young diamond-back terrapins was obtained during the past summer at the United States Fisheries Biological Station at Beaufort, N. C., which operates the world's largest hatchery for the propagation of these salt-marsh turtles. The greatest annual production prior to this time was that obtained in 1935, when a brood of 13,245 was produced in the 5 concrete breeding pens surrounding the station. Artificial propagation of terrapin was first undertaken here in 1909, and since then has yielded over 128,000 young diamond-backs for restocking the coastal salt marshes of North Carolina and other Southern States. The 1938 brood has been placed in special hibernating boxes in the large rearing house and next spring will be distributed throughout the South Atlantic region in cooperation with the various State conservation departments.

This year's high production is attributed to improvements that were made in breeding pen arrangements as a result of experimental studies conducted under the direction of Dr. Prytherch and Capt. Charles Hatsel. Since these studies indicated that production of young might be considerably increased by allowing the brood stock greater room for feeding, egg laying, etc., two large pens were constructed to relieve the crowding of adult terrapin in the other five enclosures. In the new pens, in which the brood stock was allowed approximately twice as much space as during the previous year, the production of young by each group (consisting of 400 females and 100 males) increased from 1,200 and 2,480, respectively, in 1937 to 3,360 and 3,616 in 1938. In two other experiments, in which the number of adult terrapin per pen was reduced 50 percent, there were increases of 25 and 40 percent in production of young in 1938. In the various experimental pens in which crowding was reduced, the average production of young per female terrapin showed increases of 3.0 to 5.2; 3.0 to 8.41; 6.2 to 8.4; and 8.0 to 10.1, as compared with the previous year. A most encouraging aspect of these improvements in terrapin propagation is that general conditions in 1938 were apparently less favorable for breeding than usual, as two of the "control" pens that were not changed in any respect showed decreases in egg production of 20 and 50 percent.

The total brood stock at present consists of 570 males and 2,025 females, most of which have been in captivity for periods ranging from 10 to 25 years. Last season 320 wild terrapin were added to this stock and are being kept under observation in a separate pen to determine the length of time required to reach satisfactory egg production. During the first summer these terrapin produced only a few young but showed an increased output of 460 for 1938. In experiments conducted in cooperation with Dr. Bert Cunningham, of Duke University, several hundred eggs were successfully incubated under artificial laboratory conditions by keeping them in holders of

moist filter paper instead of in a layer of sand, as in nature. This new technique will be valuable in future experiments to determine the relative importance of various environmental factors such as temperature, humidity, oxygen supply, etc., on the rate of incubation and survival of young of the diamond-back terrapin.

Utilization of salt-marsh ponds for propagation of fish and shellfish.—Investigations have been undertaken to determine the possibility of using improved marsh areas in the South Atlantic coastal region for breeding and growing mullet, oysters, and other marine species of commercial importance. In cooperation with the Works Progress Administration the construction of a large tidal pond, 2½ acres in extent, for experimental rearing of mullet was completed by the fall of 1938. This was stocked with over 3,000 fish ranging in size from roe mullet, weighing over 5 pounds, to immature fish having a length of 6 to 8 inches and which are approximately 1 year old. Less than 1 percent of the fish died from injuries sustained during collection and transportation to the pond by live car. The tidal circulation renews over half the water in the pond every 12 hours and apparently has maintained, during the first 3 months of operation, satisfactory conditions for breeding and feeding of the mullet. This is indicated by the discovery of thousands of very young mullet in the pond during the latter part of December which had attained lengths ranging from one-half to three-fourths of an inch. Representative samples of these small mullet are being collected at intervals of 1 month in order to obtain a record of their rate of growth in this experimental area. Observations are also being made of the growth of the large mullet and the time required for the various age groups or schools to reach marketable size. The experiments thus far have shown that tidal ponds of this type can also be used for the temporary storage of comparatively large quantities of live fish until conditions for marketing are most suitable.

Construction operations were continued on marshland adjacent to the mullet-rearing pond to provide shallow canals and small ponds for experiments in oyster culture. These were planted in the early fall with several hundred bushels of seed oysters gathered from nearby beds where overcrowding produces an inferior quality of oyster. In the artificial ponds the oysters have shown rapid growth during the first 3 months, October through December, but the real test as to the practical value of this procedure will come during the summer of 1939, when arrangements will be put into effect to protect these plantings from attachment of spawn and subsequent crowding. Detailed observations of the rate of growth of the seed oysters in weight, volume, etc., are being made by the use of cement panels to which representative groups of oysters have been fastened, in order that individual measurements may be obtained at regular intervals. Different conditions are being maintained and studied in the various ponds with respect to temperature, depth, and circulation of water in relation to the density of oyster plantings and time required for the seed to reach marketable size.

APPROPRIATIONS

The funds for the work of the Division of Scientific Inquiry in the calendar year 1938 were approximately the same as for 1937 insofar as the basic appropriation is concerned. The lifting of the require-

ment for administrative saving, however, made available $30,000 which was held in reserve the previous year. The sum of $76,000 was added to the appropriation in order to finance the new Bristol Bay salmon investigation. An appropriation specifically for conserving fish by screens and ladders was provided in the amount of $20,000. By means of special deposit funds made available by the States of Virginia and Maine, investigations were conducted on the oyster and lobster fisheries, respectively. Large allotments of Public Works Administration and Works Progress Administration funds made possible the construction projects undertaken by the Division to improve the biological stations at Milford, Conn., Beaufort, N. C., and Pensacola, Fla., as well as to construct fish screens in the States of Washington, Oregon, and Idaho. In addition to these projects statistical work on old fishery records was conducted at Cambridge, Mass., Ann Arbor, Mich., and Stanford University, Calif. About one-third of the emergency funds and about one-half of the two regular appropriations was spent in the calendar year 1938. A statement of funds available for biological investigations is given below:

Project	1938	1939
Regular appropriations:		
Commercial fishery investigations	$133, 181	$222, 300
Oyster cultural investigations	50, 579	50, 620
Aquiculture investigations	42, 500	46, 880
Conserving fish by screens and ladders	1, 500	20, 000
Water quality studies	----------	11, 100
Washington laboratory and administration	4, 240	7, 100
Total	232, 000	358, 000
Allotment for travelling expenses	27, 000	31, 620
Allotment for maintenance and operation of vessels	29, 000	30, 450
Special funds:		
Marine fouling studies	1, 500	----------
State of Virginia oyster fund	----------	5, 000
State of Maine lobster fund	----------	2, 500
Public Works Administration projects	----------	281, 050
Works Progress Administration projects	----------	127, 645

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